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See Jupiter & Saturn both at opposition this month

#195 AUGUST 2021

# Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

## BLUE MARVEL

The view of our planet from space, from iconic Apollo photos to today's climate monitoring satellites

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Get ready for great conditions to watch summer's best meteor shower

### TREASURES OF THE TEAPOT

Track down sights beyond the Milky Way in Sagittarius

### JUNO'S JOURNEY CONTINUES

What a 4-year extension means for the mission at Jupiter

### ICE-BOUND OCEANS

Hidden seas on the moons of Uranus & Neptune

### NEAR-SPACE WEATHER

Tracking the observation of noctilucent clouds

### ON TEST THIS MONTH

Image editing software & an app-enabled telescope

# Welcome

## Look at our world afresh, from a vantagepoint of space

As well as looking up at what the night sky has in store, this issue we're also reversing the view and looking back at planet Earth from space. In our feature on **page 36**, Rob Banino speaks to scientists operating satellite missions monitoring our planet's vital statistics, to investigate how they will provide the data that will underpin global agreements addressing rising levels of carbon dioxide in Earth's atmosphere.

The view remains reversed for another feature too, where Toby Ord tells us about his project to digitally restore photographs of Earth taken by Apollo astronauts. On their way to and from the Moon, the Apollo crews were the first – and so far only – humans to see our planet from the vantagepoint of deep space, and it was a sight that marked a shift in our relationship with our home world. Turn to **page 34** to see these iconic images in a new light.

With the promise of near-perfect conditions this month for the peak of the Perseids, we switch back to looking out at the night sky. Will Gater gets you ready for one of the best meteor showers of the year with his feature on **page 28**, before Pete Lawrence provides advice on how to image the dynamic event in wide-field on **page 76**, and how to capture a meteor train, the lingering evidence of a bright bolide, in 'The Sky Guide' on **page 55** (fingers crossed!)

We also have details in 'The Sky Guide' for observing the oppositions of Saturn and Jupiter, both this month, and on **page 60** Ezzy Pearson tells us what to expect from NASA's mission to Jupiter, Juno, after its recent four-year extension.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 12 September.


## HOW TO CONTACT US

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9:30am–5:30pm, Mon–Fri
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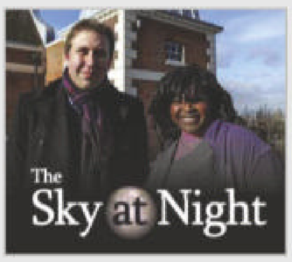
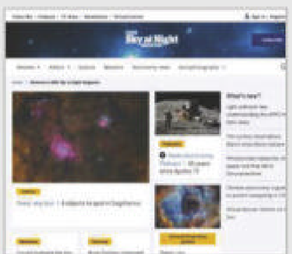
## Sky at Night – lots of ways to enjoy the night sky...




### Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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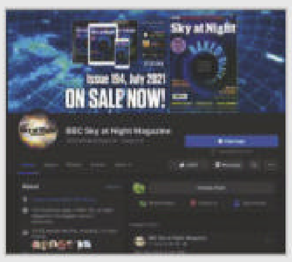


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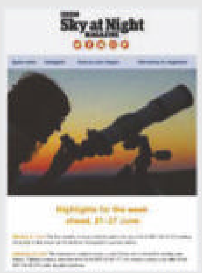


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C = on the cover

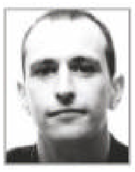
# New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**


## This month's contributors

### Rob Banino

**Science Journalist**



"We have to cut our $CO_2$ emissions to avoid climate change, but without knowing how much $CO_2$ we're responsible for, we can't tell if our efforts work." **Rob discovers the satellites that monitor the gases in Earth's atmosphere, page 36**

### Ezzy Pearson

**News editor**

"Considering Juno was supposed to be ending this month, looking into all the things it has planned during its extended mission was thrilling." **Ezzy looks forward to what's next for Juno as its Jupiter mission is extended, page 60**

### Emily Winterburn

**Physicist & historian**

"I enjoyed writing about noctilucent clouds, and noticing how as astronomers' interests have changed, so too has our understanding of this phenomenon." **Emily looks at the ongoing discovery of NLCs, page 72**

# Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/QR33ZSQ/** to access this month's selection of exclusive Bonus Content

## AUGUST HIGHLIGHTS

### How to make the Universe from scratch

Interview: particle physicist Dr Harry Cliff traces the building blocks of the cosmos back to the Big Bang.

### Watch *The Sky at Night: Space Boom Britain*

Maggie and Chris reveal how the British space industry plays a vital role in humanity's exploration of the Universe.

### Astrophoto gallery: Solar eclipse special

View our pick of the best images of the 10 June partial solar eclipse sent to us by *BBC Sky at Night Magazine* readers.

### The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

# QUICK AS A FLASH

**Super-fast stellar winds in RCW 120 are triggering star creation more rapidly than we thought possible**

**SOFIA/SPITZER SPACE TELESCOPE, 4 JUNE 2021**

This glowing shell, 4,300 lightyears away in the constellation of Scorpius, the Scorpion may offer us a glimpse into how new stars formed in the early Universe.

Emission nebula RCW 120 is sculpted by stellar winds blasting from an immense star at its heart. In this new composite of data from NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) and the now-defunct Spitzer Space Telescope, blue shows the gas expanding towards Earth; red is the gas travelling away.

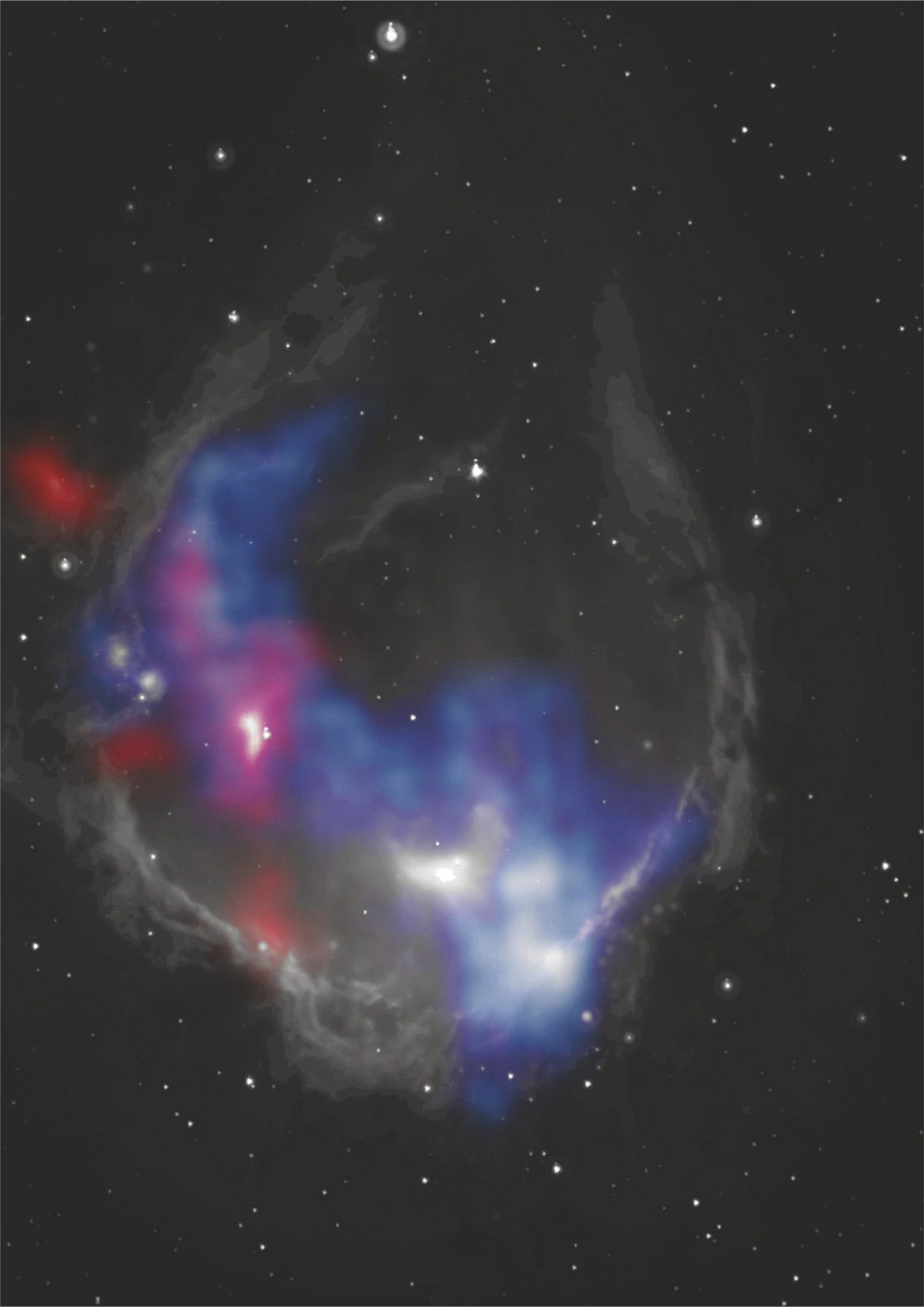
New research has measured the expansion speed of the glowing gas and found it to be moving at 53,000km/h. When it hits the surrounding medium, the gas compresses, triggering the formation of dense clumps along the nebula's rim, areas jam-packed with new stars.

The blistering velocity of expansion suggests star formation can be a far more fast and furious process than previously thought. It also shows that RCW 120 is something of a whippersnapper – a youthful 150,000 years old.

NASA/JPL-CALTECH/SOFIA

MORE **ONLINE**

**A gallery of these and more stunning space images**



## △ Over the moon

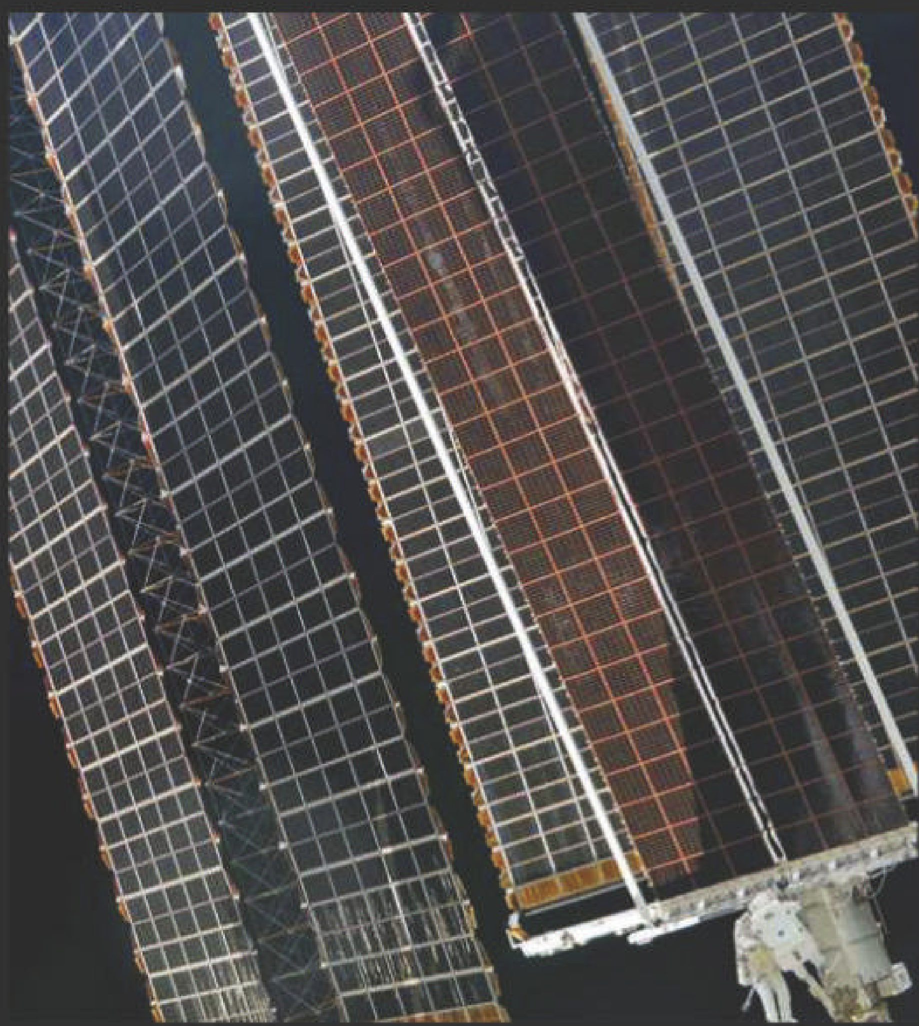
**JUNO, 7 JUNE 2021**

Daubed in dark and light, criss-crossed with lines and spattered with craters, Jupiter's icy moon Ganymede is captured here with incredible clarity. Flying within 1,038km of the surface, Juno's was the closest approach to the largest moon in our Solar System since the Galileo orbiter in 1997. To the left of centre you can see the vertical line of Enki Catena, a 161km-long chain of craters formed when an incoming comet broke apart and struck the moon's surface. This photo was processed by citizen scientist Kevin McGill. You can download and make your own versions of Juno's raw images at **www.missionjuno.swri.edu/junocam/processing**

## Power up ▷

**INTERNATIONAL SPACE STATION, 20 JUNE 2021**

Astronauts Shane Kimbrough and Thomas Pesquet (bottom) look tiny in comparison to the new 20m roll-out solar array they are installing on the International Space Station (ISS). This is the first of six new iROSA arrays to be fitted to supplement the Space Station's 20-year-old, iconic – but inefficient – solar panels. The installation involved a 6.5-hour spacewalk and a 28-page instruction manual, and was complicated by a malfunction in Kimbrough's spacesuit.

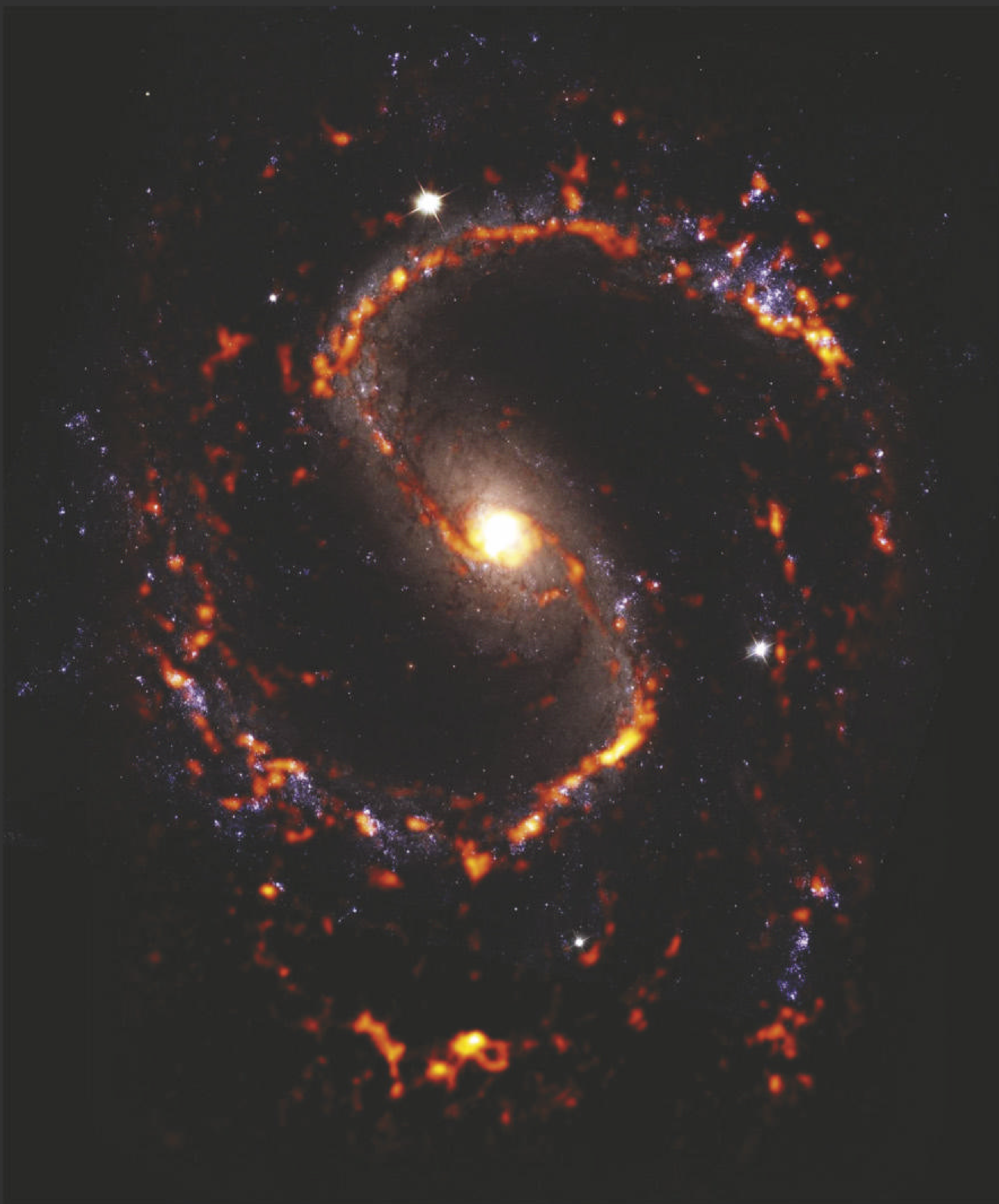


NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M. GILL, OLEG NOVITSKIY/ROSCOSMOS, X-RAY: NASA/CXC/PENN STATE/K. GETMAN, ET AL; INFRARED: NASA/JPL/SPITZER, ALMA (ESO/NAOJ/NRAO)/ESA/NASA/PHANGS/S. DAGNELLO (NRAO)

## When suns lash out ▷

**CHANDRA X-RAY OBSERVATORY/SPITZER SPACE TELESCOPE, 16 JUNE 2021**

The Lagoon Nebula, M8, is among the targets of a huge 24,000-star X-ray survey of super and mega-flares: outbursts from stars up to 10 million times more energetic than the 1859 Carrington Event, that caused electrical chaos on Earth. The study is a step towards understanding whether giant flares help planets form around stars or blast away and evaporate any emerging atmospheres with their powerful radiation.



## ◁ Location, location, location

**ALMA/ HUBBLE SPACE TELESCOPE, 8 JUNE 2021**

Where you're from matters. A survey of nearly 100 galaxies, including NGC 4535 (pictured), has found that the clouds of dust and gas where stars form look and act differently depending on their place in the Universe. It's the first such wide-ranging comparison of star-forming clouds, and the first indication that where and how many stars are born is significantly affected by their wider galactic 'neighbourhood'.

# BULLETIN

Determining the amount of dark matter in galaxy NGC 1052-DF2 hinges on getting measurements of its distance from the Milky Way

## Dark matter-free galaxy confirmed

### The find challenges our knowledge of how galaxies form and stay together

**A distant** galaxy could throw our understanding of galactic formation into question, after recent Hubble Space Telescope measurements have bolstered previous claims that it's free of dark matter.

According to our current understanding, galaxies are held together by a mysterious substance known as dark matter. Spheroidal galaxy NGC 1052-DF2 (DF2 for short), however, seems to be an exception to this rule. Although it is as wide as the Milky Way, the galaxy contains 200 times fewer stars, and initial measurements (made in 2018) suggest that it has 400 times less dark matter than astronomers think it should have – according to our current understanding of how galaxies grow and evolve.

An alternate possibility, however, is that the galaxy is closer than its initial measurement of 65 million lightyears. This would make it intrinsically fainter, meaning it has less mass and less dark matter. To test if this was the case, astronomers used Hubble's Advanced Camera for Surveys to look at the red giant stars within DF2. Red giant stars all peak with the same brightness, so astronomers can use them to work out how far away the objects they lie within are.

The new observations reveal that not only is the galaxy as distant as initially thought, but it's actually further away – at a distance of 72 million lightyears from the Milky Way.

"What you see is normally only the tip of the iceberg with Hubble," says Pieter van Dokkum from Yale University, who led the Hubble observations. "But in this case, what you see is what you get. Hubble really shows the entire thing. That's it: it's not just the tip of the iceberg, it's the whole iceberg."

**https://hubblesite.org**

ALYSSA PAGAN (STSCI), NASA/JAXA/ISAS/DARTS/DAMIA BOUIC/VR2PLANETS, NASA/SMITHSONIAN INSTITUTION/LOCKHEED CORPORATION, NASA/JPL-CALTECH

### Comment

**by Chris Lintott**

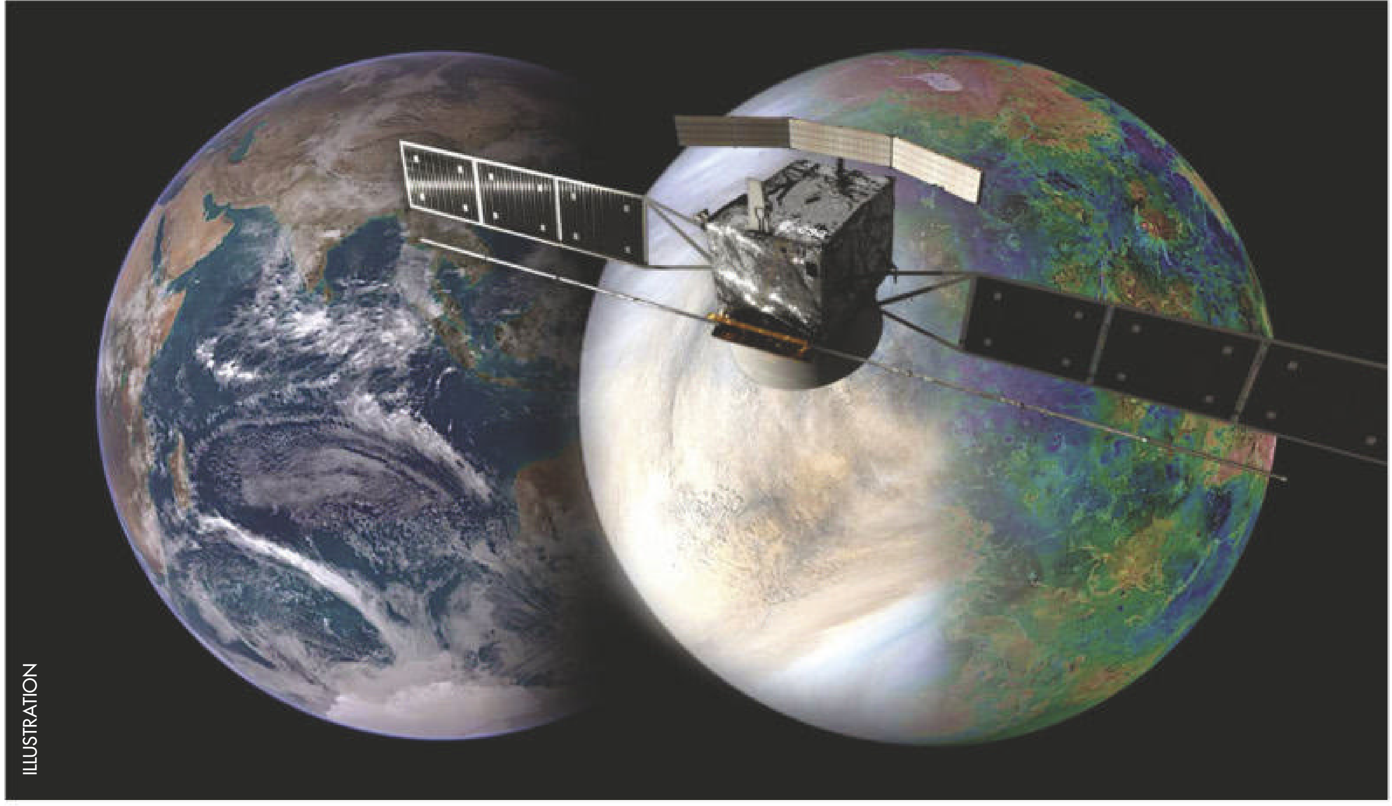
Since its discovery, DF2 has caused controversy. Detecting the influence of dark matter on small systems is a difficult task, and showing it isn't there is very hard.

This also adds strength to claims about the dark matter-free status of another satellite of NGC 1052-DF4, which has similar properties to DF2.

These results challenge our 'standard' conception of how galaxies form in a Universe dominated by dark matter, and alternative ideas that remove any need for mysterious particles by fiddling with the theory of gravity.

With new clues needed by both sides of that great debate, I'd expect more observations of this intriguing system in the near future.

**Chris Lintott co-presents *The Sky at Night***




▲ ESA's EnVision mission will compare the atmosphere of Venus (right) with Earth (left)

# UK scientists to lead the way to Venus

New mission will investigate the planet's geology and atmosphere

**The UK** is to play a key role in an upcoming mission to study the planet Venus, EnVision. The spacecraft, selected in June by the European Space Agency (ESA), is a €610m project to study both Venus's thick atmosphere and the surface volcanic activity which created it. It will be equipped with a radar system capable of penetrating not only the thick cloud, but the surface layer of the planet. It will also use spectrometers to pick out key gases in the atmosphere. The team will then take these findings and compare them with what we know about other planets, including Earth, hoping to gain some insight into why ours is the only planet that we know of with life.

"EnVision will take that experience to Venus to make sense of our most un-Earthly neighbour, and so help us understand what makes our own world so special," says Richard Ghail from Royal Holloway University of London, lead scientist on the project.
**www.esa.int**

# Hubble instrument computer glitch spells trouble

▲ The Hubble Space Telescope has experienced problems before

**The Hubble** Space Telescope went into safe mode on 13 June, following a fault in its payload computer. As of writing, several attempts to recover the telescope have been unsuccessful.

The payload computer, built in the 1980s, controls the telescope's science instruments and monitors the telescope's performance. It initially failed to send its 'handshake' signal to the main computer. This automatically put its instruments into safe mode to prevent them being damaged. Mission controllers initially tried resetting the computer without success, before tracking down the issue to the computer's memory module. They then attempted to transfer to one of the three backup modules, but the command failed to complete.

After 30 years in space, the telescope is beginning to show its age, and this isn't the first time it has experienced computer problems. Back on 7 March, the telescope suffered a software fault, which put it out of action for five days before being remedied. The Hubble team say they will continue attempting to get the spacecraft back online and doing science.
**www.nasa.gov**

## NEWS IN BRIEF


### Disc-less dwarfs

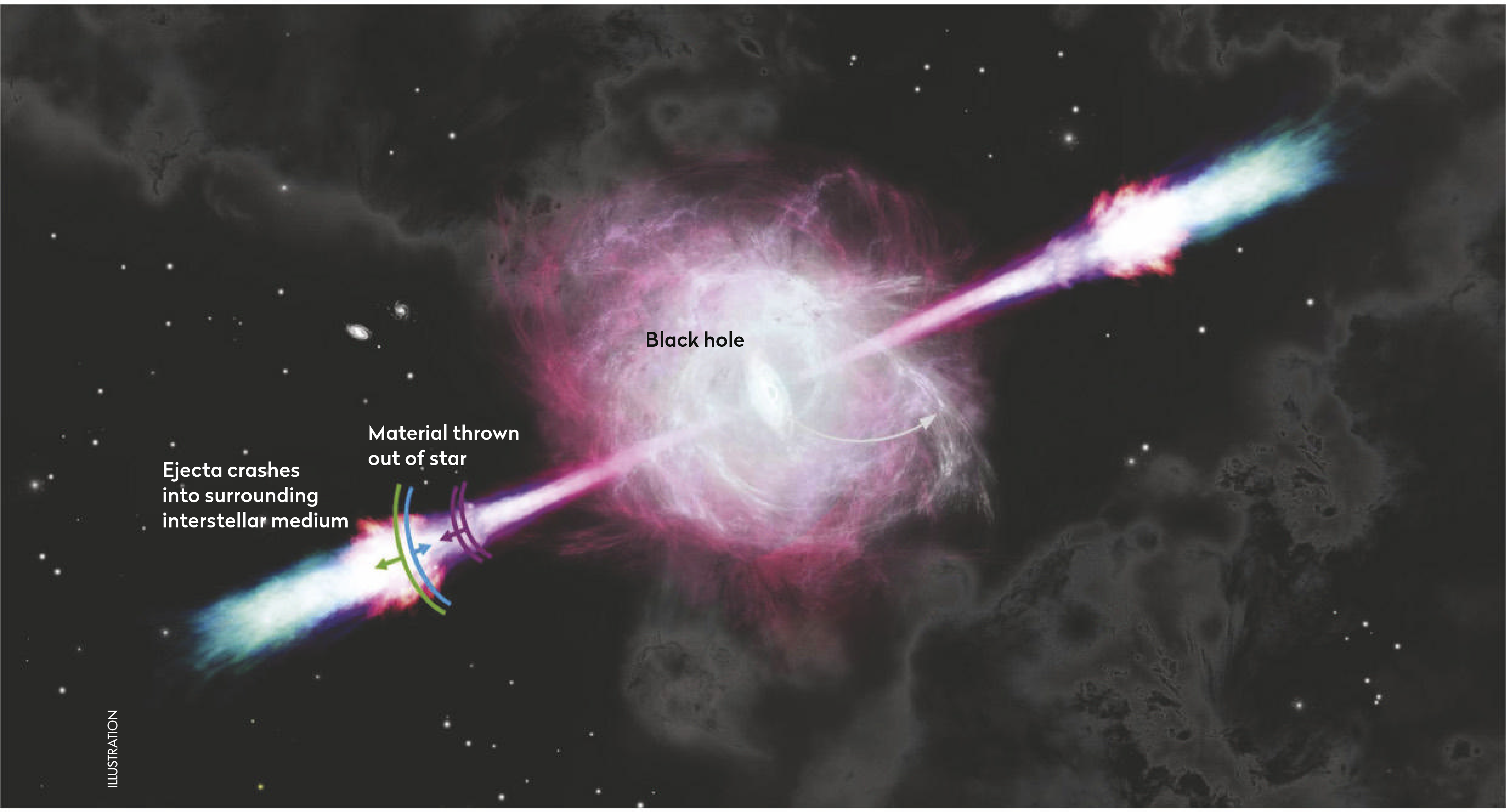
The dusty ring of debris found around white dwarf stars only appears after 10–20 million years, according to a recent study. When the dwarfs first appear, after a Sun-like star goes through its red giant phase, they are so hot they vaporise the surrounding debris, preventing a disc from forming.

### 500 radio bursts

The Canadian Hydrogen Intensity Mapping Experiment (CHIME) detected 535 fast radio bursts in its first year of operations. Before CHIME, only 140 of the mysterious bursts – which last only a fraction of a second – had been detected since their discovery in 2007.

### Colossal comet

An impressive 100km-wide comet, believed to have originated in the distant Oort cloud, was spotted creeping into the inner Solar System in June. Comet C/2014 UN271 is currently 20 times the Earth–Sun distance away, and will make its closest approach in 2031, passing just beyond the orbit of Saturn.




▲ Scientists have been studying how the magnetic fields of gamma-ray bursts behave during the explosive formation of black holes

# Gamma-ray bursts scramble their magnetic fields

## The find could help astronomers understand what makes these events so energetic

**Gamma-ray** bursts (GRBs) scramble their magnetic fields within minutes, a new study has found, confirming a decade-old theory about how these explosions are created.

GRBs are rapid eruptions of energy created when a massive star – at least 40 times larger than the Sun – reaches the end of its life and collapses to form a black hole. These extreme events throw out stellar material at velocities approaching the speed of light, which creates a short-lived flash of gamma radiation we then detect here on Earth.

It's thought that magnetic fields play a critical role in making GRBs so extreme, but exactly what role is unclear. The theory is that these fields thread themselves through the material thrown out by the collapsing star, but these soon become twisted by the spinning of the newly created black hole. Then, as the advancing debris crashes into the surrounding interstellar material, the magnetic fields get disrupted and eventually destroyed.

Testing this theory, however, has proven difficult. It is impossible to see these magnetic fields directly, meaning that astronomers have to look for the hallmarks they leave behind in the light given off by the gas they run through.

"We measured a special property of the light – polarisation – to directly probe the physical properties of the magnetic field powering the explosion," says Carole Mundell from the University of Bath, who led the study.

However, these observations require a different type of telescope to the kind that can spot GRBs in the first place. There is only a short time frame to turn a follow-up telescope onto the position of a burst before the magnetic fields are destroyed and there is no more polarised light to observe.

But Mundell's team made arrangements for the robotic Liverpool Telescope in La Palma to automatically slew to the location of any new GRB as soon as it was spotted, and managed to get follow-up data just 90 seconds after the gamma radiation reached Earth. Using this method, they could track how the magnetic fields moved and decayed after the explosion, finding they were rapidly obliterated in the minutes following the initial blast.

"This is a great result and solves a long-standing puzzle of these extreme cosmic blasts – a puzzle I've been studying for a long time," says Mundell. **www.bath.ac.uk**

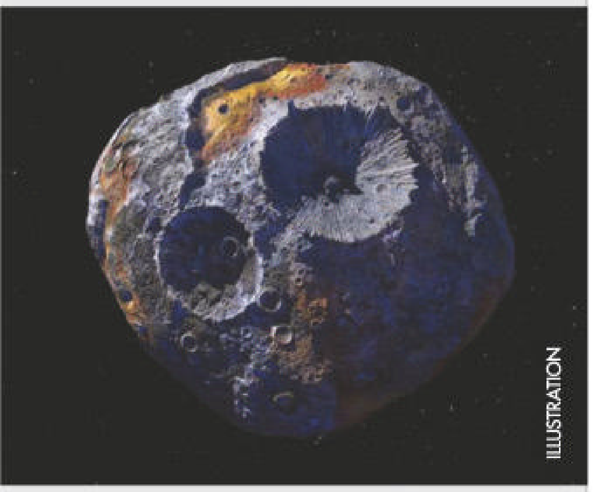
NURIA JORDANA-MITJANS, NASA

# Replacement solar panels for ISS

Astronauts Shane Kimbrough and Thomas Pesquet conducted three spacewalks in June to install new solar panels on the International Space Station (ISS). The six panels are a new 'roll out' design, and are wrapped up to make them easier to transport. Once installed, the arrays took 10 minutes to unfurl.

The panels replaced several of the ISS's original solar arrays, which had been in operation since December 2000. After 20 years, their efficiency was beginning to drop, but these new arrays returned the station to its original power output.

# NEWS IN BRIEF



ILLUSTRATION

### Asteroid light on metals

A team of geologists have endeavoured to recreate the surface regolith of asteroid 16 Psyche, finding it to be richer in metals than previously thought. As the asteroid is believed to be the remains of a failed planet, the finding could have implications for our understanding of planetary cores.

### Space tourists to take off

Jeff Bezos, founder of spaceflight company Blue Origin, is set to fly on the first human test flight of the New Shepard spacecraft on 20 July, along with his brother Mark. A fellow space tourist bid $28 million for a third seat on the flight, which will transport the trio to the edge of space for just 11 minutes before returning to Earth.

### Observatory destroyed

The Scottish Dark Sky Observatory in Galloway Forest was extensively damaged by a fire in the early hours of 23 June. Police currently investigating the fire's cause are treating it as suspicious, and are appealing to anyone who might have information on the incident to come forward.

MAXAR/ASU/P.RUBIN/NASA/JPL-CALTECH, XINHUA GLOBAL SERVICE, AMANDA SMITH, CARL KNOX/OZGRAV/SWINBURNE UNIVERSITY

BULLETIN

# Crew boards Chinese space station

## Tiangong is still under construction with more crew flights planned

The Chinese astronauts (from left) Tang Hongbo, Nie Haisheng and Liu Boming arrive at Tiangong

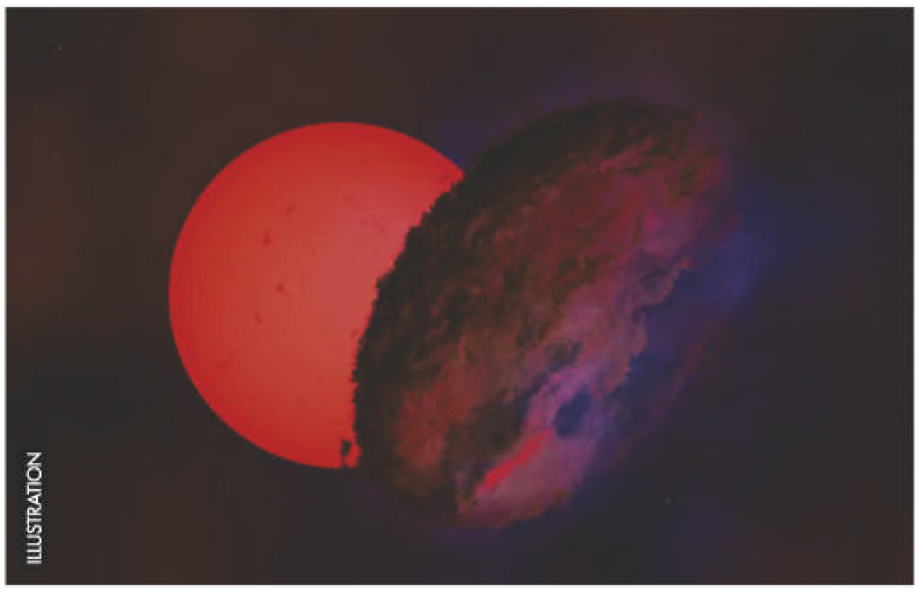
**China's new** permanent space station, Tiangong, received its first crew on 17 June. The three-person crew will remain on the station for at least 33 days, setting a new record for Chinese spaceflight. During this time, the team will verify the station's life support systems, as well as conduct a spacewalk using suits brought up by a previous cargo flight.

"We need to set up our new home in space and test a series of new technologies," says Nie Haisheng, the mission's commander.

Currently, the station only has one module – the core module, Tianhe – meaning the crew will be living and working in a space just 16.6m-long and 4.2m-wide. Two more science modules will be sent to the station in 2022 and these will be installed by future crews.

**http://en.cmse.gov.cn/**

# Blinking stars hide behind companions



ILLUSTRATION

▲ While many stars change in brightness, it's rare for one to become fainter over several months and then brighten again

**Astronomers recently** spotted a star 'blinking' out of the night sky before returning to full brightness over the course of a few months. The star, known as VVV-WIT-08, dropped in brightness by around 30 times, making it almost invisible.

"Occasionally we find variable stars that don't fit into any established category, which we call 'what is this?', or 'WIT' objects," says Professor Philip Lucas from the University of Hertfordshire, who helped lead the project.

It's thought the star, which is estimated to be 25,000 lightyears away, is a new class of binary system, where a giant star 100 times larger than the Sun is accompanied by an as yet unseen orbital companion. This partner could be a star or a planet that is surrounded by an opaque disc, which eclipses the star when it passes. Other 'blinking' stars have been seen in the past, but none dimmed quite as much as VVV-WIT-08.

"There are certainly more to be found, but the challenge now is in figuring out what the hidden companions are and how they came to be surrounded by discs, despite orbiting so far from the giant star," said Leigh Smith from the University of Cambridge, who led the study.

**www.cam.ac.uk**

# First extreme pairs spotted

A new piece has been added to the puzzle of gravitational waves, following the first ever detections of waves from a 'mixed' source – one where both a neutron star and a black hole collide.

Two such events were spotted back in January 2020 by the LIGO and Virgo gravitational wave observatories, but their origin was only recently confirmed.

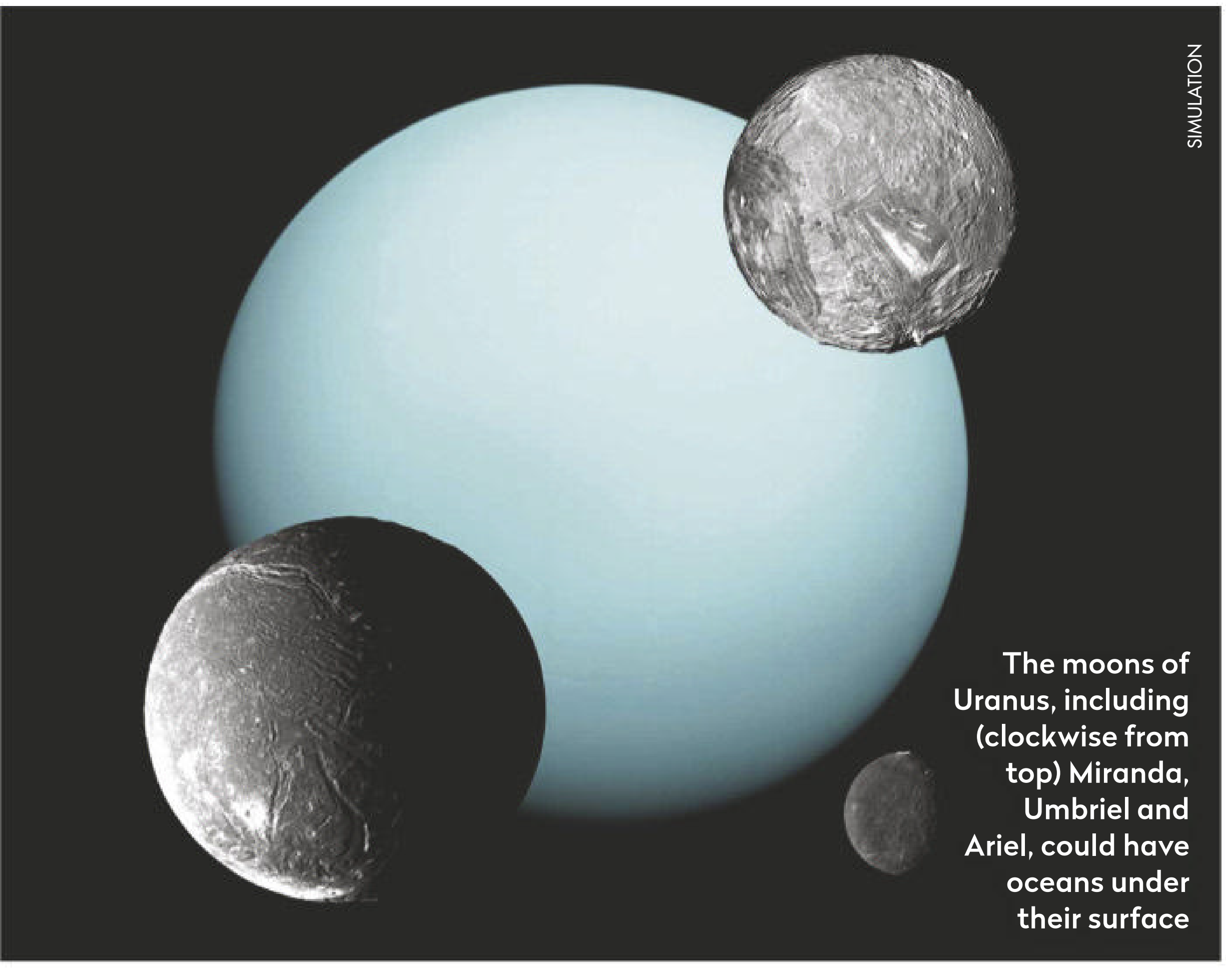
It's been theorised for decades that there are binary systems featuring a black hole and a neutron star, but none have been found within our Galaxy.

"These are our first robust detections of neutron-star–black-hole mergers. This important new source of gravitational waves could help us answer crucial questions about how, and where, neutron stars and black holes form in the cosmos," says Prof Sheila Rowan, director of the University of Glasgow's Institute for Gravitational Research and part of the LIGO collaboration.

The illustration here shows one of these mixed sources, a neutron star spiralling into a black hole.

ILLUSTRATION

# CUTTING EDGE




The moons of Uranus, including (clockwise from top) Miranda, Umbriel and Ariel, could have oceans under their surface

## Hunting oceans on Uranus's moons

The planet's magnetic field could help to see beneath the icy surface of its moons

While the Galileo probe was looping around the Jovian system in the 1990s it detected something very strange about two of the larger moons. Galileo was equipped with a magnetometer – an instrument for measuring magnetic fields, a bit like an extremely sensitive compass needle – and every time the spacecraft performed a flyby of Europa or Callisto it sensed the field lines of Jupiter's powerful magnetic field draping around the moons. The satellites seemed to possess a weak magnetic field that was interacting with that of Jupiter.

These tiny, frozen moons can't have been generating the magnetic field themselves by an active internal dynamo, as happens in Jupiter and Earth's molten metal cores. It was being created indirectly, as the moons moved through Jupiter's own field. In order for this induced magnetic field to arise, there must be a layer of something hidden beneath the frozen face of the moons that is electrically conductive. By far the most likely option was salty water – Europa and Callisto both harbour subsurface oceans, and it is these that are interacting with Jupiter's magnetic field.

### Detecting oceans

This same technique could be used to remotely sense the presence of subsurface oceans on other moons too. Corey Cochrane at the Jet Propulsion Laboratory and his colleagues argue that Uranus and Neptune also offer a great opportunity for using magnetic sounding to detect oceans within their moons. Neptune has only one major moon, Triton, which is thought to be a captured Kuiper Belt Object that destroyed Neptune's original system of satellites when it arrived. But Uranus has a diverse family of moons (named after Shakespearean characters), including Puck, Miranda, Ariel, Umbriel and Oberon.

Voyager 2 visited both the Uranus and Neptune systems, but it didn't pass close enough to any of the moons to detect the tell-tale signature of magnetic induction. Photographs taken by the probe, however, show widespread evidence in the landscapes on both Miranda and Ariel of recent tectonic and cryovolcanic activity – perhaps these moons have subsurface liquid water oceans that persist even today. And Cochrane says that available technology could readily detect such oceans with just a single flyby.

*"Does evidence of recent tectonic and cryovolcanic activity [on both Miranda and Ariel] suggest these moons have subsurface liquid water oceans?"*

What's more, Uranus's quirky magnetic field would allow a probe to deduce a great deal about a subsurface ocean. The ice giant's magnetic field is not only pretty intense, but crucially is tilted significantly relative to the orbits of the major moons – by around 60° – and is also offset from the centre of the planet. The planet's satellites experience a magnetic field that is constantly varying. The induction effects of this within the moon's interior mean that researchers could even start working out the depth, thickness and conductivity of different subsurface layers.

**Prof Lewis Dartnell** is an astrobiologist at the University of Westminster

**Lewis Dartnell** was reading… *In Search of Subsurface Oceans within the Uranian Moons* by CJ Cochrane et al.
**Read it online at: https://arxiv.org/abs/2105.06087**

# Black holes among the Green Peas

Compact, green galaxies could help reveal the history of our own

**Prof Chris Lintott** is an astrophysicist and co-presenter on *The Sky at Night*

The most exciting words to hear in science, according to the late science-fiction legend Isaac Asimov, are not 'Eureka! I have found it', but rather 'That's funny...'. Like him, I've always been attracted by finding the odd and unusual things lurking in the Universe, hoping that their unique stories can shed a light on how the rest of the galaxies, stars and planets spend their lives.

The Zooniverse project, which I'm lucky enough to lead, involves hundreds of thousands of volunteers sorting through data to make discoveries. One of the earliest discoveries – the small, round green galaxies called 'Peas' – has proved to be the most exciting of all.

These systems are dwarf galaxies which exist in some of the least populated parts of our Universe. Soon after the discovery by the volunteer 'Peas Corps', it was clear that the distinctive colour was due to the glow of excited oxygen, itself an indication of remarkable star-forming activity. In fact, the Peas are the most efficient stellar factories in the local Universe. Some think that they seem to be the local equivalent of the galaxies that hosted the first big burst of star formation 10 billion years ago, which lit up the Universe in a period known as 'Cosmic noon'.

**"The Peas are the most efficient stellar factories in the local Universe – the equivalent of the galaxies which hosted the first big burst of star formation"**

## More than meets the eye

It's this resemblance which has made the Green Peas a subject of further study and caused a bit of controversy. A new paper, led by a team from Arizona State University, suggests there may be more to them than meets the eye. A large survey by NASA's WISE (Wide-field Infrared Survey Explorer) satellite of infrared observations of 500 Peas identified more than 50 as likely active galactic nuclei (AGN), which are hosts to growing black holes at their centres.

It is now well known that most large galaxies, including the Milky Way, host supermassive black holes, but how and when these black holes grow is not well understood. If the Peas are best understood as stragglers – only now, thanks to their remote position and small size, getting around to what most larger galaxies experienced billions of years ago – then perhaps we should expect their black holes to just be forming, too. By looking at these systems we might be getting a view of our own Galaxy's distant past.

It's not easy, though. The classic Pea combination of high levels of star formation, combined with nearly pristine, low metallicity gas, make the normal methods of identifying AGN very tricky. The systems studied here have the right infrared colours to suggest AGN activity, and 38 of them also seem to flicker at these wavelengths, which is at least consistent with material falling down onto a central black hole.

Now we know which are promising targets, these Green Pea galaxies can be targeted for follow-up investigations with telescopes from across the electromagnetic spectrum – from those sensitive to the X-rays created by hot gas around the putative black holes to radio telescopes. Confirmation of growing black holes will tell us a great deal about these strange systems and, with any luck, their more normal cousins.

The hunt for Green Pea galaxies has been swept along by citizen scientists. The distinctive colour is due to the glow of excited oxygen

**Chris Lintott** was reading... *Evidence for Black Holes in Green Peas from WISE colors and variability* by Santosh Harish.
**Read it online at: https://arxiv.org/abs/2105.13400**

*The Sky at Night* TV show, past, present and future

# INSIDE THE SKY AT NIGHT

▲ **There are many fascinating clips to choose from – when it comes to looking back through six decades of *The Sky at Night* in the BBC's archives**

The July episode of *The Sky at Night* looks at a topic close to the producer and director **Keaton Stone**'s heart – the search for alien life

*The Sky At Night* may not boast the glitz and glamour of other television shows, but to me it is and has always been essential viewing. Ignited, as I was, with a passion for the heavens at an early age, it was Sir Patrick Moore – through the show he was so synonymous with for 55 years and his many (so many!) books – that would further inspire me to take my passion for astronomy as far as I could. I have been incredibly fortunate to still have some small involvement in the subject by working on this, most special, of programmes from time to time over the years.

It was therefore a real privilege to be asked to make this year's bumper, hour-long, special edition of the show and even more of a treat when it was decided it would revolve around the search for life in the Universe; a topic I have always been especially fascinated with. However, the little twist we applied to it – so it would stand out from the many other programmes on the subject – was that we would look at the quest through the lens of how the BBC has reported upon it over the years. Of course, being the BBC, we are fortunate to have such an extensive archive. To have the chance to dig out some long-forgotten clips dating back through six decades of broadcasting was not only a fabulous foundation to construct a unique programme around – but it was also a thrill to be able to trawl through them all.

The more eagle-eyed readers may have noticed that I have talked in terms of how the 'BBC' has reported on this cosmic treasure hunt, rather than *The Sky At Night* per se. This was a deliberate decision so we could use some other magnificent

BBC X 4, IRI_SHA/ISTOCKL/GETTY IMAGES, NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M. GILL

### *THE SKY AT NIGHT* WANTS YOUR QUESTIONS

**As part of the British Science Festival 2021, *The Sky at Night* is recording a special programme on 8 September, when the presenters and special guests will be answering questions from viewers. If you have a question – on anything from space travel and technology to astronomy and astrophysics – you can email it to the programme team at: skyatnightqt@bbc.co.uk**



**Keaton Stone** is a producer and director of *The Sky at Night*

moments from our big brother *Horizon*, as well as *Whicker's World*, plus some marvellous shows before my time that I never even realised existed!

Controversially perhaps, I'm not going to say too much about the show itself, as I don't want to give too much away and besides, I imagine the title 'ET and the BBC' is enough to reel in readers of this magazine! But a few highlights for me involve Patrick being accused of sheer arrogance for not entertaining the prospect of human life on Venus, Carl Sagan explaining why aliens might want to get frisky with our plantlife and Arthur C Clarke predicting advanced intelligent life in the cosmos would most likely be cousins of our computers.

And how could I not mention the nifty wager with Brian May that later sees Patrick pop-up to claim his winnings from the confines of a posthumous future cyberspace!

In a programme like this, which lives or dies by the material sourced and how completely disparate moments over different decades are strung together to tell a compelling story, I'd like to bring your attention to the efforts of archive producer Martin West and editor Saul Budd. Such roles are often overlooked in the programmes we make, so I hope you'll join me in acknowledging their brilliant handiwork when you watch the episode.

# Looking back: The Sky at Night

## 31 August 1991

On 31 August 1991 episode of *The Sky at Night*, Patrick Moore took a look at one of the most famous stars in the night sky – Polaris. Also known as the Pole Star, or North Star, Polaris's position directly over the North Pole means it appears to stay static through the night, a quality that navigators and astronomers alike have used to find their way around the night sky for hundreds of years. Conveniently, it is the 46th brightest star in the night sky, meaning it is easy to spot.

**▲ Due to its brightness, Polaris is easy to spot, even in light-polluted skies**

Polaris is in fact a triple system, made up of two stars about the mass of the Sun flanking a larger, five solar mass star. The North Star is located around 440 lightyears away, meaning the light we see from it left it centuries ago, when the Crusades were occurring here on Earth.

Despite its current importance, Polaris hasn't always been directly over the Pole, nor will it remain there forever. The Earth's axis precesses, meaning it wobbles like a spinning top, tracing out circles on the night sky and causing the Pole to drift away from Polaris. In 3,000 AD, the North Star will be Gamma (γ) Cephei in Cepheus. By 10,000 AD it will be Deneb (Alpha (α) Cygni), before drifting back to Polaris in 27,800 AD.

## The Sky at Night AUGUST

### Exploring Jupiter

This month there are two anniversaries for the price of one! The National Space Centre in Leicester is 20 years old and NASA's Juno space probe is 10. Recorded at the National Space Centre, *The Sky at Night* looks at the achievements of the Jupiter explorer. Chris and Maggie speak to Juno's Principal Investigator Scott Bolton and members of the UK Juno team, Jonathan Nichols and Leigh Fletcher.

BBC Four, **8 August**, 10pm (first repeat BBC Four, **12 August,** 7:30pm)
**Check www.bbc.co.uk/skyatnight for more up-to-date information**

**▲ Juno has enabled scientists to look at Jupiter's atmosphere in great detail**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

# INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

**MESSAGE OF THE MONTH**

This month's top prize: two Philip's titles.

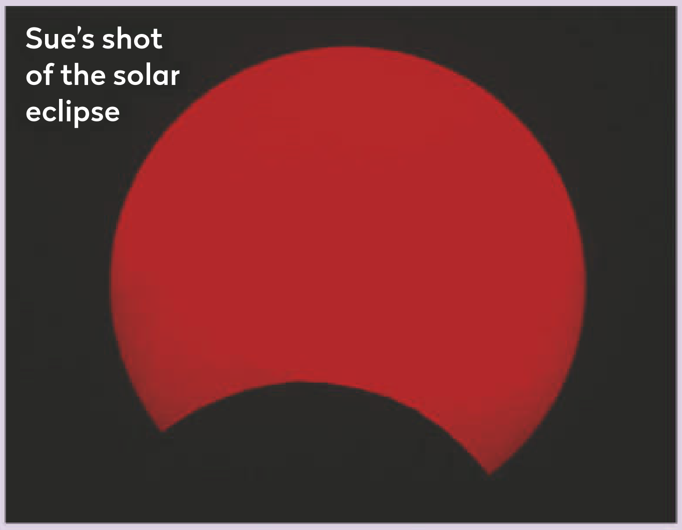

**PHILIP'S** The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Heather Couper and Nigel Henbest's *2021 Stargazing* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

## A break in the clouds

I had been looking forward to the solar eclipse on 10 June, even though I knew I'd only see a partial eclipse from my location – we just needed the weather to be kind to us. So naturally I awoke to a very grey Sheffield morning. It wasn't just cloudy; it was a grey blanket. I couldn't even see where the Sun should be, so I would have to trust my mount to find it for me. I set up my Lunt LS60THa/B600 solar scope and Canon EOS 1100D DSLR on a Sky-Watcher EQ5 Pro mount just in case, but there was no improvement at the time of the first contact. Around 10:45am, however, I noticed the sky was brighter and went out to have a look. There were a few breaks in the clouds and what looked like a possible blue patch.

I quickly got into position and waited. Then suddenly the Sun was out! There was no time to check the focus; I'd practised finding it during the week so just went with that. I took this single shot at 10:58am with ISO 200 at 1/50", the Sun already retreating into the clouds when I tried to take another. It never cleared again. I got that one chance, but I'm more than happy with it and glad I got a hydrogen-alpha image. There is only a little surface detail to see, but just visible are two small prominences. As I was processing the image with GIMP I noticed the unevenness of contours on the Moon's surface against the Sun. I'm so glad I was prepared – what a result from an otherwise grey morning! **Sue Silver, Sheffield**


Sue's shot of the solar eclipse

*What a wonderful account, Sue. It just goes to show that it pays to be ready. Well done! – **Ed***

## Tweet

**Richard Crabtree**
@R_Crabtree1 • 19 June
A great display of #noctilucent clouds last night. Taken around 23:30 from Bradford West Yorkshire. @NLCalerts @ bbcweather @GoStargazing @Bradford_TandA @ThePhotoHour @skyatnightmag

Students enjoy eclipse-watching in Wigan

## Group effort

Students at Wigan & Leigh College were excited to witness the partial solar eclipse on 10 June, and with help from lecturer Robert Kavanagh and our A-Level physics students we set up an observation session to safely observe it. It was a brilliant opportunity to witness the celestial mechanics of Earth with our natural satellite – the Moon. The students wore eclipse glasses to observe safety, and I had set up my telescope and digital camera to capture a clear close-up view. Seeing all the science students and teachers observing was a real display of our shared passion for natural science.
**Antonio Coulton, Wigan & Leigh College, Wigan**

## An essential guide

I first bought a reflector about five years ago and used it without any real direction. Then, last winter, I revisited the hobby and upgraded to an 8-inch Dobsonian. However, I cannot imagine how I'd have kept my love for this hobby alive without subscribing to *Sky at Night Magazine*. As I haven't seen a monthly subscription recommended as an essential bit of kit for a beginner on the

online groups and social media forums, I just wanted to get the message out there!

My first bit of advice I would give to anyone thinking about buying a telescope would be this: forget posh eyepieces, motor drives, Go-To systems and whatever else, and invest in a *Sky at Night Magazine* subscription because you'll be lost in a sea of stars without it.
**Darren Lee, via email**

## Only human?

In your June issue ('Eye on the Sky', page 8) you covered the Ingenuity helicopter making the first powered, controlled flight on another world. What intrigued me was you said it was 'the first (human made) powered, controlled flight on another world.' Are you trying to tease us about something you know but cannot confirm?
**Neil Graham, Hollingworth**

Apologies for any confusion! 'Human-made' was used to contrast the controlled drone flight with programmed flights, such as the Sky Crane that put Perseverance on Mars. ***– Ed.*** ▸

## ON FACEBOOK

**WE ASKED: What got you into astronomy?**

**Andi Reeves** I've always been fascinated with space, but my wife bought me a telescope for my birthday a few years ago. I spent ages trying to find Jupiter, and when I did it grabbed my imagination like nothing before. It blew my mind that I was looking at something so far away from my little light-polluted garden, standing there with the biggest grin on my face like I was the first person to see it. And from that moment I was hooked!

**David Jones** It was my primary school teacher, Mr Magee. He let me watch the Apollo 11 Moon landing at school when I was nine. I went to school in Greenwich and he took me and some friends to the planetarium for a talk with Patrick Moore. I was introduced to him and he signed my copy of *The Look-It-Up Book of Stars and Planets*. I've been hooked ever since.

**Wil Cheung** As a seven-year-old I was inspired by Sir Patrick Moore and the Voyager probes. I was set on pursuing a career in astronomy, but at the age of 14 the careers advisor said, "No, there's no money in it. An astronomer makes only £12,000 a year." (This was in the 1990s). I studied business instead but I became an armchair astronomer. Twenty years later I started to volunteer at a nearby observatory, helping out an average of 20 nights per month alongside a full-time job. Now six years on, I host my own stargazing events in Northumberland Dark Sky Park, sharing the beauty of the Universe with other folks.

**Emma Richardson** My mum: on clear nights she used to get out the blankets and rugs and we would all cuddle up on top of the picnic bench in the garden and watch the night sky go by!

**Michael Boschat** In 1960 my mother took me to the library. I went to the science section and picked out books on astronomy, geology and dinosaurs. I re-read the book on astronomy and got another on the subject, and I was hooked. My first books were *Your Book of Astronomy* and *The Boys' Book of Astronomy* by Patrick Moore. I sent him letters and got replies and talked to him on the phone in later years. We didn't get his TV programme here in Canada and he wasn't a household name, but 61 years later I'm still doing astronomy, all thanks to him. It was a sad day when he passed away, but he is among the stars he loved.

# SCOPE DOCTOR

**Our equipment specialist cures your optical ailments and technical maladies**

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

***I'm buying my first telescope or set of binoculars. What can I get for around £500 if I want to look at the planets and perhaps some other celestial bodies? I also have a Nikon D5300 DSLR camera, can I use this for astrophotography?***
**KEITH WILSON**

It would probably make most sense for you to start with an all-rounder system to get a feel for astronomy and then decide what aspect really interests you. Binoculars are a great idea, but a basic telescope would give you greater flexibility towards your aims. Within your £500 budget, a 200mm aperture Dobsonian telescope would be a great choice – and you'd still have £100 left to purchase a couple of good eyepieces to complement the two average ones supplied with the kit. A 200mm Dobsonian's focal length is long enough to achieve reasonable views of the planets and the aperture is large enough to allow you to observe numerous deep-sky objects.

Though the Nikon D5300 is capable of capturing great images, deep-sky objects like galaxies and nebulae require a tracking mount and planetary imaging needs a longer focal length telescope. With a Dobsonian you would be limited to short exposures of large bright objects like the Moon and starscapes of the constellations.

**▲ A 200mm Dobsonian will give good views of the planets and the deep sky**

WWW.FIRSTLIGHTOPTICS.COM

## *Steve's top tip*

***Do I need to let my telescope cool down before observing?***

Just as unstable air in our atmosphere warps and distorts the light reaching our eyes from celestial objects, so too does the air inside a telescope tube have the propensity for spoiling the view. The column of air within your telescope generates a miniature version of atmospheric disturbance in the form of tube currents as it tries to reach temperature equilibrium with the air outside. These tube currents distort and diffract the light from celestial objects, destroying fine detail and giving stars odd smeared shapes, so allowing time for your telescope to cool down is an important part of the pre-observing routine.

**Steve Richards is a keen astro imager and an astronomy equipment expert**

BBC Sky at Night MAGAZINE

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**EDITORIAL**
**Editor** Chris Bramley
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**News Editor** Ezzy Pearson
**Staff Writer** Iain Todd
**Reviews Editor** Paul Money

**CONTRIBUTORS**
Rob Banino, Lewis Dartnell, Glenn Dawes, Dave Eagle, Ben Evans, Will Gater, Pete Lawrence, Chris Lintott, Mary McIntyre, Laura Nuttall, Toby Ord, Jheni Osman, Jonathan Powell, Steve Richards, Giles Sparrow, Keaton Stone, Steve Tonkin, Peter Ward, Jane Williamson, Jenny Winder, Emily Winterburn, Paul Wootton

**ADVERTISING SALES**
**Advertising Manager** Andy Williams
+44 (0)117 300 8803, Andy.Williams@immediate.co.uk
**Inserts** Laurence Robertson +353 (0)87 690 2208

**PRODUCTION**
**Production Director** Sarah Powell
**Production Coordinator** Lauren Morris
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**Ad Coordinator** Charles Thurlow
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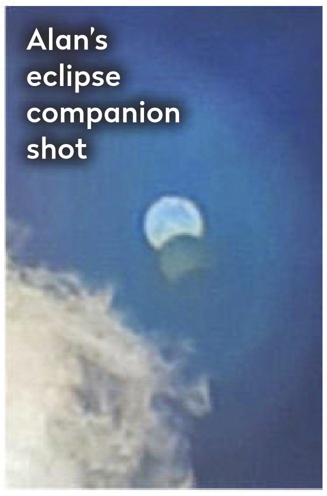
## An eclipse enigma


Alan's eclipse companion shot

▸ I took some good shots of the partial eclipse with my mobile phone on 10 June, but I noticed some show the eclipse 'nudging' the top of the Sun and other shots show it nudging the bottom. There are other shots where it looks like the Sun has a duller companion too. Can you tell me why this happened.
**Alan Percival, via email**

As the Sun was quite high in the sky when the eclipse happened, were you holding your phone high overhead, Alan? It may have got its orientation mixed up and shown the photo upside-down. The duller companion may be a lens artefact. ***– Ed.***

## Instagram


**darren_flinders • 17 June**

In these warm summer nights, I find it harder to sleep than usual, but it does give me the chance to admire the Moon floating by my window.
#moon #luna #astrophotography #moonphases #moonphotography @bbcskyatnightmag @yorkshirepics @ your_yorkshire @bbcearth

## Moore memories

Back in 1966, as President of Plymouth Astronomical Society, I was in regular contact with Patrick Moore and asked him about holding a meeting of the BAA Lunar Section in Plymouth. During his talk he showed what was, I believe, the first ever astronomical picture taken by a CCD camera. He instinctively knew the name of every star in the image and was able to tell us the limiting magnitude of the short exposure. The meeting remains memorable for that reason alone, but it was also a milestone in regional BAA meetings.
**Lawrence Harris, Stowupland**

## SOCIETY IN FOCUS

▲ **Left to right: Wendy Keys, Emma Hugo and Carol Miller outside the Community Centre**

**Lanivet Amateur Astronomers**, based in Lanivet, Cornwall, began life in February 2018 when three women, Emma Hugo, Wendy Keys and Carol Miller got together for a coffee and a conversation about astronomy and space exploration. By the end of that day we'd set up a Facebook group; and by the end of the month we'd begun an after-school astronomy club at the local primary school and held our first meeting in the car park of our not-quite-finished new Community Centre. Eight people turned up on that first night.

Once the Community Centre opened in May we met every third Friday of the month, with numbers between 10 and 20 people. Wendy gave talks on her interest in stars and constellations, Emma on her interest in space exploration and Carol on the planets and the Moon. We had other speakers from within the group and from other Cornwall astronomy groups.

On clearer nights we'd go outside with binoculars and telescopes, helping each other to be informed about the night sky, assisting newcomers with their kit and inspiring others to come along through the Facebook group and word of mouth.

Fast forward to 2021, and the Facebook group has continued to grow and we now have over 200 members, but COVID-19 has meant that we haven't met for over 12 months. We look forward to meeting again in autumn for a new season of astronomy.
**Carol Miller, co-founder, Lanivet Amateur Astronomers**
▸ **Visit the Facebook page of Lanivet Amateur Astronomers for more info**


We pick the best live and virtual astronomy events and resources this month

# WHAT'S ON

## DOCUMENTARY

### Online The Edge of All We Know

An exhilarating documentary following the physicists working with Stephen Hawking on his final paper, on the black hole information paradox, and the Event Horizon Telescope team as they race to image a black hole (located at the centre of galaxy M87) for the first time. **www.netflix.com**

## TALKS

### Live Dark Sky site tour

**OM Dark Sky Park, Omagh, during August**

Travel through the Universe with your own star guide, experience space in virtual reality and ponder the mysterious connections between the sky and the area's ancient stone circles. Tickets are £5 (adults) and £3.50 (children). Pre-booking is essential via **omdarksky.com**

### Live One Day on Mars

**Royal Observatory Greenwich, during August**

Enjoy a thrilling full-dome planetarium show touring the dunes and canyons of the Red Planet. Adult tickets are £10 and children are £5. To book, call 020 8312 6608, or visit **www.rmg.co.uk/whats-on/planetarium-shows/one-day-on-mars**

### Online Red quasars

**15 August, 7pm**

Sunderland Astronomy Society (SAS) hosts this Zoom talk on red quasars and their important role in galaxy evolution, with Victoria Fawcett of Durham University. To join, email a request to **zoom-meetings@sunderlandastro.com**

BBC X 4

## PICK OF THE MONTH


▲ Dip into the BBC vaults and discover landmark broadcasts from the Space Race and beyond

### Online Explore the BBC archive

**Relive the drama of past space missions and discover a wealth of space science interviews**

The short, summer nights are a good time to trawl through space programmes in the BBC archive. Stretching back over decades, there are classic moments aplenty, from James Burke's live reaction to Apollo 13's safe return, to a vintage *Sky at Night* episode where Sir Patrick Moore met Pluto's discoverer Clyde Tombaugh.

*Horizon* gives us 1966's 'Man in Space' on the everyday life of NASA's astronauts, a 1981-era 'Race to Ruin' on space weaponry, and an interview with cosmonaut Valentina Tereshkova. A 1969 *Panorama* looks at Moon mission costs, while a 1987 *Tomorrow's World* covers the 'Race to Mars'. **bbc.co.uk/archive/collections**

## COURSE

### Online An Introduction to Astronomy

**Starts 15 August**

This five-month distance learning course from Liverpool John Moores University is for non-experts and covers the history of modern astronomy, the origins of our Solar System, the life cycles of our stars and the different structures of the galaxies.

The course costs £225; you can find information on this and other short courses at **www.astronomy.ac.uk**

## CRAFT

### Online Make your own Webb

With the James Webb Space Telescope soon to launch (it's currently forecast for October 2021), this European Space Agency (ESA) project involves making your own spacecraft from household items such as Lego, food, painting or sewing.

You can then share your creation via #WebbAtHome on Twitter or Instagram, with ESA goodies going to the best entries. More information and entry details are available on the ESA website: **bit.ly/3iXqJgM**

# FIELD OF VIEW

## An astronomer's best friend?

### Jonathan Powell weighs up the stargazing companionship of cats and dogs

MICHAEL PARKIN/FOLIO

**Jonathan Powell** is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he has written three books on astronomy and is currently astronomy columnist at the *South Wales Argus*

Some of us revel in the solitude of darkness and the accompanying silence when observing the night sky, as we connect in our own special way with the Universe. But, aside from the odd twitching curtain or the unwelcome dazzling headlights of a neighbour returning home late, we astronomers know we're not the only ones enjoying the tranquillity. With dark adaptation sharpening night vision and a more finely tuned sense of hearing in the silence, one becomes aware of nature's nightlife around us, and the owls, bats, rodents and foxes who are using the hours of darkness to conduct their nocturnal business.

While wild animals aren't overly bothered with what we astronomers are up to, our pets generally are, and two main players present themselves as possible after-dusk partners. Firstly there's the faithful dog, who may take an interest in proceedings for a time, until this wanes when the prospect of something cosy and potentially edible inside the house proves too much a temptation. With an offering of some parting words such as, "I'll leave you to it then!" the dog will duly toddle off inside.

Then there's the cat who, after probably watching rather nonchalantly from a distance, will eventually decide to investigate what one of its 'staff' could be possibly doing at this time of night. In stealth mode, the cat will gently engage with a nudge against the lower leg. Then, with some customary meowing, which loosely translates as, "It's me, the cat, you may make a fuss," like a drill sergeant the cat will duly undertake an inspection. If the astronomer is of a nervous disposition when the cat first rubs against the lower leg, there is a flustered attempt not to bang any part of the body on the telescope or accompanying equipment (the first priorities lie with not disturbing the object being viewed in the eyepiece).

Throughout history the lives of the cat and their science-based owners intertwine, physicist Nikola Tesla's cat Macak and Einstein's cat Tiger to name but two. American astronomer Edwin Hubble's cat Nicolas Copernicus was often found sprawling across astronomical charts, and then there was Austrian physicist Erwin Schrödinger and his cat – or possibly not! Sir Patrick Moore cared for two cats in his boyhood years, Ginger and Ptolemy, then later Jeannie and another Ptolemy. Astrophysicist and musician Brian May immortalised the passing of Pixie, his childhood cat, in the song 'All Dead, All Dead' on Queen's 1977 album *News of the World*.

Granted, and for the sake of balance, an elk and a parrot also jostle their way into the science arena, along with Dolly the Sheep. And let us not forget the pooch completely: Russian physiologist Ivan Pavlov had his salivating dogs; Laika was the first dog to orbit Earth; and there was Marjorie, the diabetic dog who helped isolate insulin.

Dogs are the doers of this world while cats are the thinkers, or should that be schemers and plotters? Overall however, which would appear to be top dog? Well, in this astronomer's world, it's the cat.

# Perseid PERFECTION

**The peak of this year's Perseid meteor shower promises to be a fine sight under dark skies. Will Gater gets you ready for the show**

Summertime astronomy in the UK can be something of a bleary-eyed marathon, with late-night observing sessions to grasp anything that seems like darkness amid the glow of twilight. Every August, though, we get our reward for persevering through these months in the form of the Perseid meteor shower and this year – if the skies are clear – we should get a decent show.

On the night of the shower's peak, on 12 August, the Moon sets at around 22:30 BST (21:30 UT), which is well before the onset of astronomical darkness for much of the country; with no moonlight to wash out the sky, fainter meteors will be easier to spot. But what causes this wonderful celestial spectacle and what do you need to do to make the most of it? That's what we're going to tackle over the following pages.

Meteors begin their lives out in the depths of space as tiny grains of dust, known as 'meteoroids'. If any of these flecks of interplanetary material are unfortunate enough to hit Earth as they travel around the Sun, they collide with our atmosphere at many kilometres per second and get vaporised in ▸

WILL GATER

With the Moon disappearing early in the evening, the conditions are looking very favourable for viewing the Perseids on 12 August

▸ the process. The narrow ribbon of light that occurs when this happens is the meteor – what many call a 'shooting star' – and they're happening all the time.

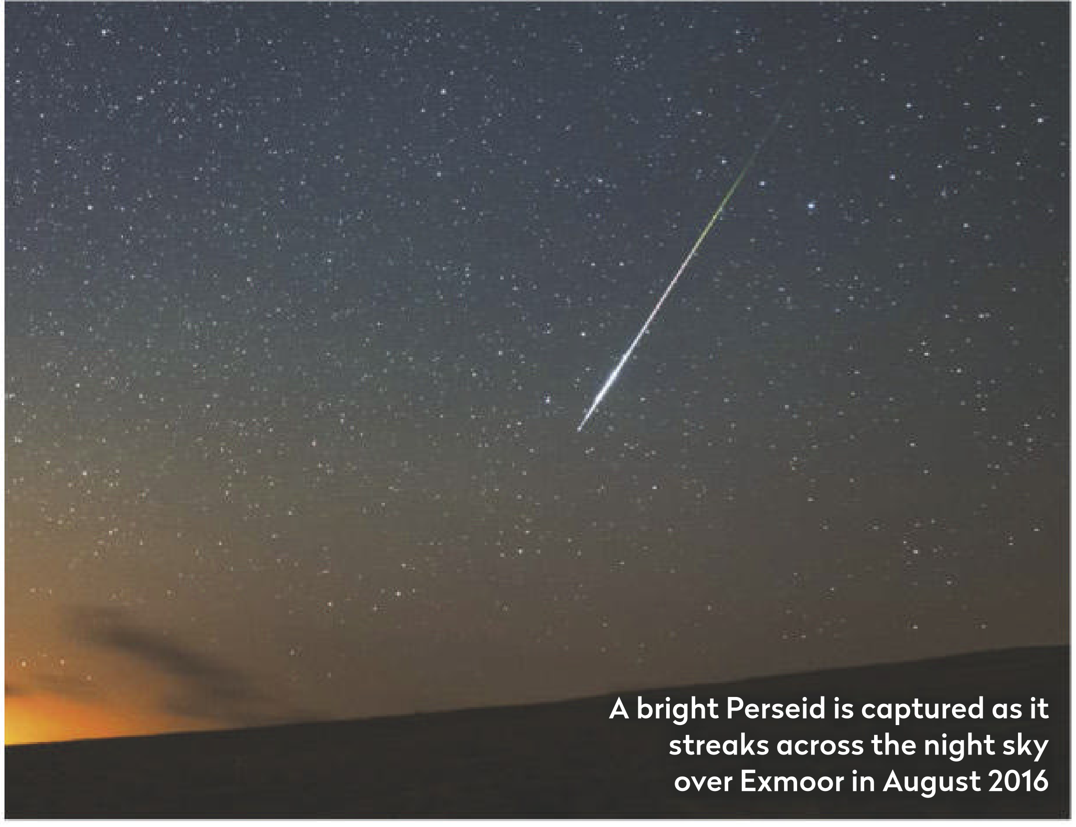
On a clear night if you look up at the stars for, say, half an hour or so, it's highly likely that you'll see a meteor at some point – especially from an observing site with dark skies. Many meteors that you see like this will be what's known as 'sporadic' meteors; essentially that means that they are random in nature and can appear anywhere in the sky, going in any direction. What's different with the Perseid meteor shower this month is that Perseids, while they can materialise anywhere against the backdrop of stars, all appear to streak from a fairly-well defined point on the sky – astronomers call it the 'radiant'.

## A trick of perspective

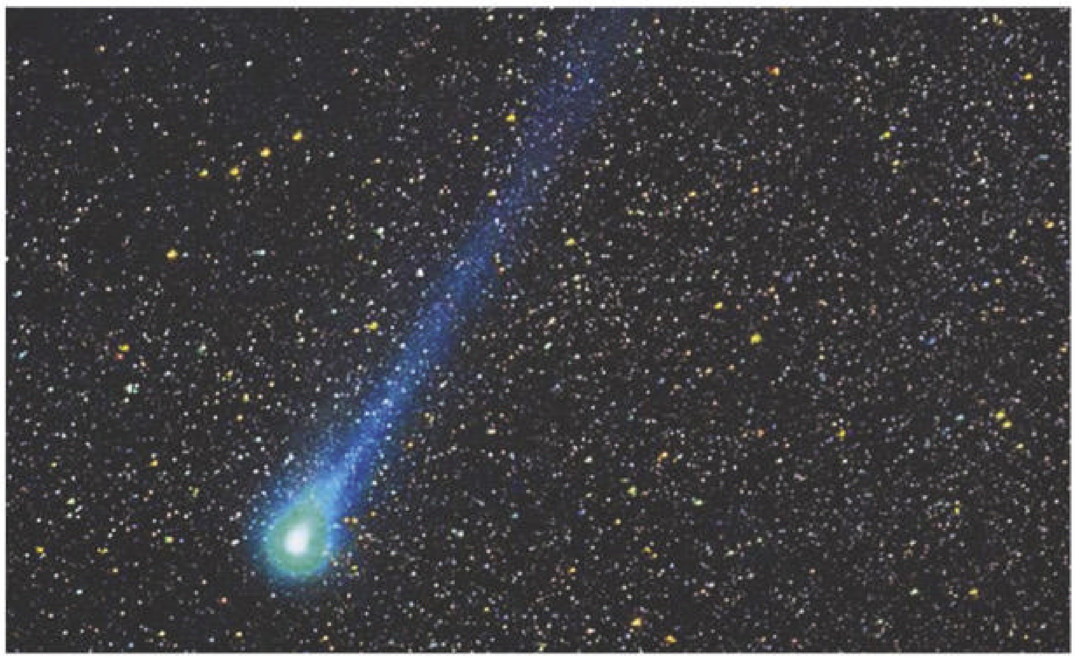
This behaviour is, in fact, an optical illusion. The meteors are actually travelling on broadly parallel paths, as the meteoroids that create them plough into the top of Earth's atmosphere. It's merely a trick of perspective that makes them look like they're zooming across the sky from the radiant point.

While 'normal' sporadic meteors originate from meteoroids scattered in a fairly random way between the planets, meteors in meteor showers like the Perseids occur when Earth passes through a stream of dusty material left by a comet or asteroid as it has journeyed around the Sun. In the case of the Perseids, that's a cloud of dust left by Comet 109P/Swift-Tuttle.

Every year Earth's orbit brings our planet into a position where its path intersects with that trail; we



A bright Perseid is captured as it streaks across the night sky over Exmoor in August 2016



▲ Comet 109P/Swift-Tuttle – the source of the Perseid meteor shower

# Recording your observations

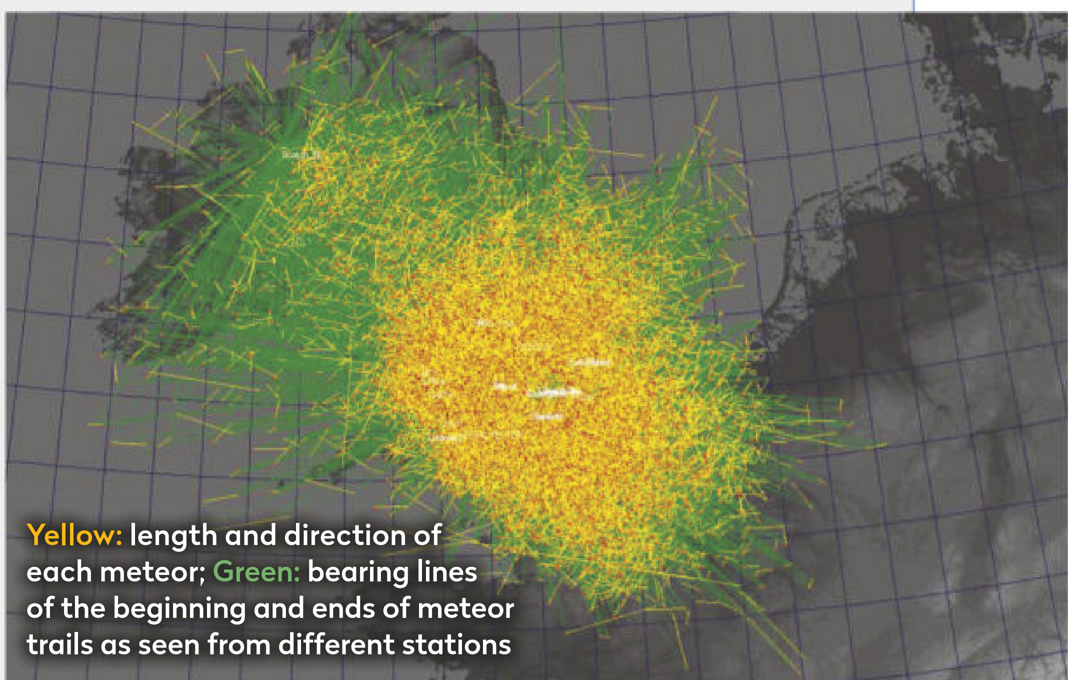
## Play a part in gathering valuable scientific data for meteor research

If you get into watching the Perseids this month, why not keep a methodical record of the meteors you see over each hour. This will make an interesting keep-sake of a successful night of observing and can aid scientists with their work too. Records of visual meteor observations are still used today by researchers as a way to gather information about the meteoroid streams left by comets and asteroids.

Pictures, video and eyewitness reports can also be a key source of useful data, particularly when it comes to bright meteors known as fireballs, as these can sometimes drop meteorites to the ground.

As these started life as fragments of other bodies in the Solar System, such as asteroids, this material can be of scientific importance and there are teams worldwide who try to recover it with the help of footage and sightings from the public, as well as dedicated camera networks.

To find out more about contributing to such 'citizen-science' projects, look at the websites of the International Meteor Organisation (**www.imo.net**), UK Meteor Network (**https://ukmeteornetwork.co.uk**) and the UK Fireball Alliance (**www.ukfall.org.uk**).



Yellow: length and direction of each meteor; Green: bearing lines of the beginning and ends of meteor trails as seen from different stations

▲ The UK Meteor Network keeps an archive of its meteor detections; this ground map shows its record for 2017's meteors

WILL GATER X 5, NASA, UKMETEORNETWORK.CO.UK

# Photographing the Perseids

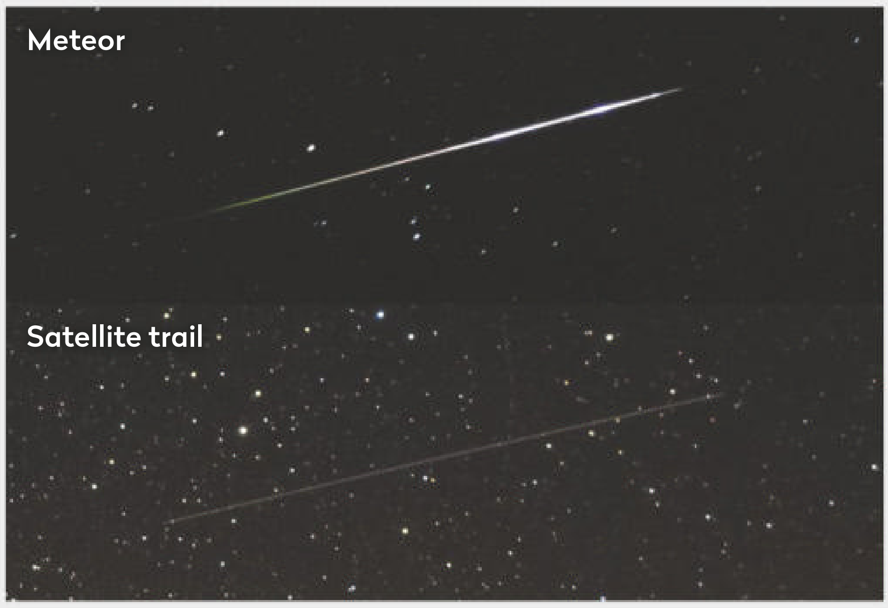
Follow our top tips and get the most from your imaging session

### 1. The basic kit

A basic DSLR or bridge camera – with a standard, wide, kit lens – and a solid photo tripod are ideal for simple meteor photography. Focus the lens by pointing at a bright star, zooming in on the Live View if you have it, and adjusting the focus ring until the star appears as small as possible. Then, set your ISO setting to a relatively high value, point your camera skyward and start taking 10 to 30 second-long exposures.

### 2. Take as many images as you can

It's really luck if a Perseid passes through your camera's field of view, so you'll want to take as many images as you can to have the best chance. This can be achieved by setting your camera to continuous shooting mode, if it has it, and using a basic cable release or an intervalometer; these usually have the ability to 'lock off' the shutter so it fires repeatedly after each exposure has finished.


### 3. Prepare for a long night

To be in with a chance of capturing a Perseid meteor, your camera's going to have to operate for a long time. Make sure you have the battery fully charged, and a couple of spares on standby if possible, as it will drain quickly in the cold with the shutter firing continuously. Watch out for dew forming on the lens too; some meteor photographers use specialist dew heaters on their camera optics to combat this.

### 4. How to identify a meteor in your shots

Meteor photography is hard. Don't be dismayed by comparisons with misleading social media pictures – many 'meteor' images online show satellite trails. Meteors tend to have a slight green tint to their 'tails' and are cocktail-stick shaped, whereas satellite trails often begin and end abruptly and are an even thickness. Short-lived shooting stars will only appear on a single exposure, but satellites often show in the frames before and after.

sail through the stream of dusty particles over the course of a few weeks and the result is the Perseid meteor shower.

While we know that the Perseid meteor shower will happen this month (see 'The Sky Guide', page 46) and that the Moon, for the most part, will be out of the way, the biggest factor affecting how good the show will be is, as always, the cloud cover on the nights around the peak. While we can't control the weather, there are many ways we can ensure that we have the best possible chance of seeing Perseids and enjoying the spectacle.

## Strength in numbers

Often when astronomers talk about the number of meteors visible during a meteor shower, like the Perseids, they neglect to mention that a great many of the meteors that make up those numbers will be ▸


Wrap up warm and recline on a sun lounger for the perfect Perseid experience

*Let your eyes adjust to the dark for 30–40 minutes, and you'll be able to glimpse much fainter meteors*

▸ fairly faint – not all meteors are alike after all. The faint ones will be hidden from observing sites with bright lights in view, changing the visual impact of the 'shower' quite dramatically. One of the key things we can do as observers to get the best experience from the Perseids is to avoid artificial light as much as possible when viewing the shower; this doesn't necessarily mean travelling to a dark-sky site – it could just be trying to keep nearby street and house lights out of your line of sight. Of course your safety is important too, so it's a good idea to have a torch with a red filter to hand to allow you to find your way.

Before you start observing it's important to let your eyes adapt to the darkness, just as you would if you were doing any other kind of visual observing of faint objects. Let your eyes adjust to the dark for a minimum of 30-40 minutes, and you'll be able to glimpse much fainter meteors when they appear.


▲ Some Perseids can be incredibly bright, lighting up the sky with a blue-green flash

## Make yourself comfortable

Perhaps the most important consideration for meteor observing is comfort. You need to put in a decent amount of time to really be in with a chance of seeing a good number of meteors, so you'll naturally want to wrap up warm, with good thermals and a warm, waterproof coat, if you have them. And keep your feet warm too as the cold can really creep up through the ground even on a warm summer night if you're standing still for long periods; insulated snow boots are great for combating this.

Ideally you'd want to lie back to view the stars, so that you can see a large swathe of sky without straining your neck; while the beauty of meteor observing is that you don't need any dedicated equipment, one of the best investments towards your overall enjoyment of a meteor shower is a reclining camp chair or sun lounger. With a setup like this, and with a rug over you and a warm drink to hand, meteor watching – especially with friends – becomes a delight.

We've tried to give you a flavour of the numbers of Perseids you might expect to see this month (see box, opposite). This is always going to be an estimated average rate as there will usually be natural lulls interspersed with more active periods in a typical meteor-watching session. It's often fun to observe in a group because of this, not just because you get a party atmosphere as you share in the excitement, but

A composite image can look impressive, but observing meteor showers, like the Perseids, is all about managing your expectations

# How many Perseids might you expect to see?

## The number of meteors seen is often less than theoretical figures

If you read some of the media coverage of meteor showers like the Perseids, you might think that, at their peak, these events see a near-constant rain of bright shooting stars blazing across the sky. Real meteor showers – while captivating and absolutely worth observing – are rarely like this. One number that's often mentioned is the Zenithal Hourly Rate, or ZHR; this is a theoretical number of meteors that would be visible, on average, over an hour with the radiant of the shower at the zenith and the viewing occurring under perfect sky conditions. The ZHR isn't a good indicator of how many meteors you can expect to see every hour, however; that figure will be lower because of things like light pollution and the typically lower radiant at the observing time. It's possible to roughly estimate how many Perseids you might spot, on average, near the peak of the shower; such a calculation suggests that while observing at around 3am (BST) on the night of the peak, a group of observers at a suburban site – where the naked-eye limiting magnitude is, say, +5 – could potentially see a rate of about 25 Perseids an hour or so.


A series of images reveals a 'persistent train' left behind by a Perseid meteor

**Will Gater** is an astronomy journalist and science presenter

also because you tend to experience more meteors as you're all looking at the sky in different directions.

The Perseids themselves can occasionally put on an impressive show of fireballs. These are brighter meteors that can light up the sky with a bright turquoise flash and are really quite thrilling to witness. Some of the brighter ones may leave what is known as a 'persistent train', which is a line of superheated air and meteor 'smoke' that appears to glow for a few seconds, and in some cases longer, after the shooting star itself has flashed across the sky.

However you intend to enjoy this month's Perseids, remember that you can also help study meteor showers by carefully recording what you either see or capture on camera. Such observations on their own might not seem important, but combined with other reports can build into something with genuine scientific value. And if the history of planetary science has taught us anything, it's that often seemingly small results can have profound implications – something that can be fun to ponder on as you watch the Perseids darting overhead on a balmy August night.

**▸ See 'The Sky Guide' for more details about when to observe the Perseids (on page 46) and for tips about photographing a meteor train (on page 55)**

A remarkable view of Earth from Apollo 16, taken on 16 April 1972, reveals a world of blue and white with a hint of brown; (inset) the image before it was digitally restored

# Portraits of our planet

**Toby Ord** has restored images of Earth captured during the Apollo missions, casting new light on the fragility of our planet

The photos of Earth against the blackness of space are perhaps the greatest legacy of the Apollo Program. As astronaut Bill Anders said on returning from the first voyage beyond Earth's orbit: "We came all this way to explore the Moon, and the most important thing is that we discovered the Earth."

Apollo images such as 'Earthrise' and 'The Blue Marble' are not just famous images of Earth, they are among the most widely reproduced photos of all time. The contrast of the delicate blue and white sphere with the inhospitable void and barren Moon became the iconic image for the growing environmentalist movement. And the image of a world without borders helped people see a world more united than divided.

But why haven't these photos, great as they are, been eclipsed by others over the last five decades? A key reason is that since the Apollo Program, astronauts have got no higher than low-Earth orbit – less than one per cent of the way to the Moon. Taking a photo of Earth from there is like taking a portrait of a friend with the camera less than a centimetre from their face. You might be able to capture the texture of their skin, but any attempt to render their entire face would be distorted. And while some of the autonomous spacecraft destined for other worlds turned their sensors around for a parting shot, their cameras weren't designed for the job, producing inferior images.

In contrast, as the Apollo astronauts travelled out towards the Moon, they reached the perfect distances for planetary portraiture. NASA had provided some of the world's best equipment for the job: Hasselblad 500 EL cameras, Zeiss lenses and 70mm Kodak Ektachrome film.

They were thus able to faithfully record Earth's true colours as they appeared to the human eye. If we look at this image from Apollo 16 (above), what we see isn't the bright green and blue circle that has come to represent our planet. Instead, it

ALL PICTURES: J-P METSAVAINIO

A lesser-known crescent earthrise, as captured from Apollo 12 on 19 November 1969

*"I was able to look out the window to see this incredible sight of the whole circle of the Earth. Oceans were crystal blue, the land was brown, and the clouds and the snow were pure white. And that jewel of Earth was just hung up in the blackness of space." – Charlie Duke, Apollo 16*

is primarily a world of blue and white, with brown continents and just a suggestion of muted green in places of lush vegetation: "I was able to look out the window to see this incredible sight of the whole circle of the Earth," said Apollo 16's Charlie Duke. "Oceans were crystal blue, the land was brown, and the clouds and the snow were pure white. And that jewel of Earth was just hung up in the blackness of space."

## Restoration mission

Struck by the beauty of the most famous photographs, I wondered if there were more. So began a journey that would occupy my evenings over the next three years. I hunted through all 18,000 Hasselblad photos from the Apollo missions for the best images that time forgot, and digitally restored them to bring out their full glory. It was these lost images of Apollo that were the real rivals to the most well-known ones.

One of my favourite hidden gems is the crescent earthrise from Apollo 12 (above). It was captured by Richard Gordon as he circled the Moon alone in the Command Module, awaiting his companions' return. It was overlooked for years as the original negative was poorly exposed and washed out. But as soon as I properly adjusted the levels, it took my breath away, revealing a haunting scene with an even more graceful and fragile view of the Earth and Moon than Apollo 8's famous 'Earthrise' photo. I chose it for the cover of my book *The Precipice*, which looks at humanity's own fragility in these challenging times.

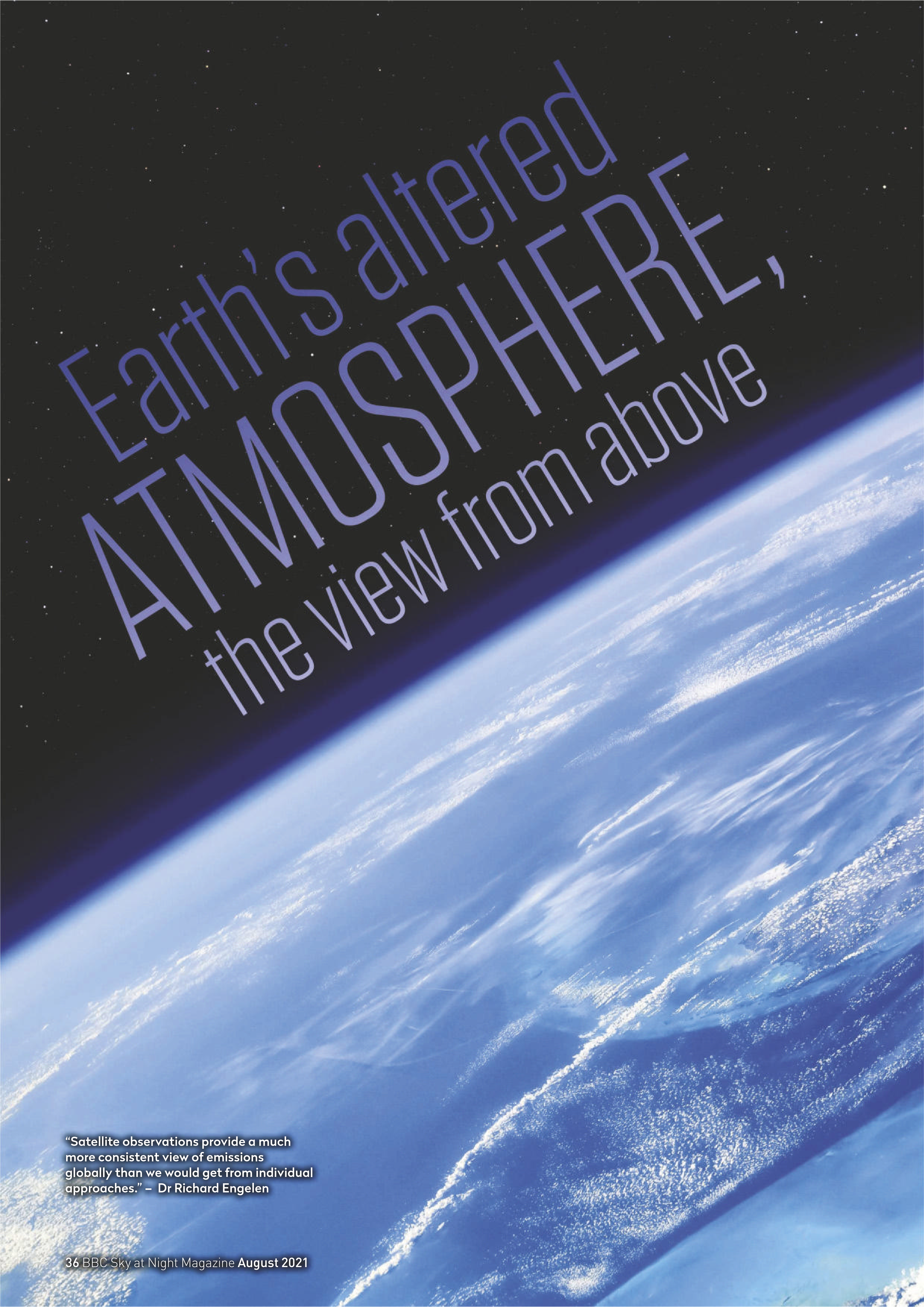
Another one of my favourite photos is from Apollo 13. Two days in, the craft suffered a dramatic explosion, venting the contents of the Service Module's oxygen tanks into space, leaving the Command Module without enough breathable air to get home. This ethereal photo (right), at first appears to show the Moon, but it is really the crescent Earth amidst the ghostly reflections of the Lunar Module. They were 80,000km and seven hours away from safety – this photo captures this stolen moment, yearning for home.

It was an absolute treat to be able to play a role in reviving these images. There are so many more great photos that have never been restored. But, since raw scans of all the images are publicly available, anyone can try their hand.

And then there is Artemis. In two years' time, Apollo's twin — the Artemis Program — will send four more astronauts to the Moon. With 50 years of advances in camera technology, their photographs will rival everything that has come before.

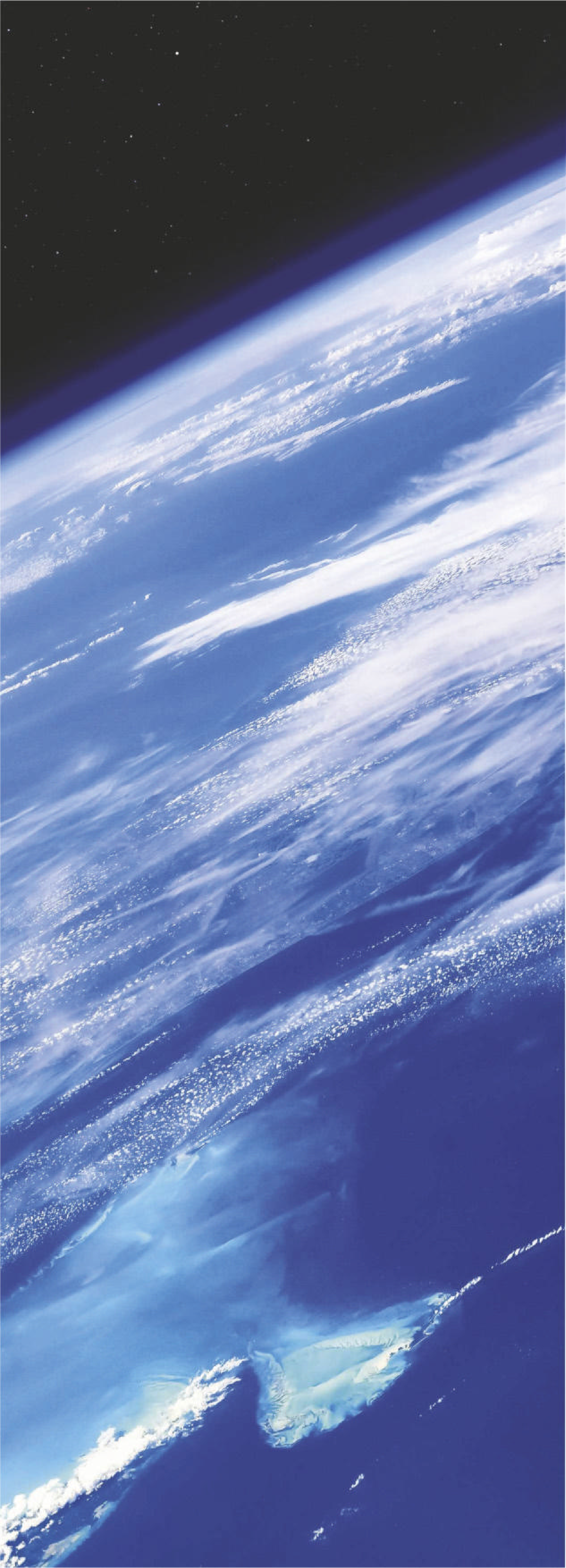
**Toby Ord** is a Senior Research Fellow at the University of Oxford and author of *The Precipice*. For all the restored photos visit **www.tobyord.com/earth**

A haunting view of a crescent Earth, as taken from inside Apollo 13's Lunar Module on 17 April 1970



# Earth's altered ATMOSPHERE, the view from above

**"Satellite observations provide a much more consistent view of emissions globally than we would get from individual approaches." – Dr Richard Engelen**



ROBERTO MACHADO NOA/ISTOCK/GETTY IMAGES

# Levels of carbon dioxide in Earth's atmosphere are rising. **Rob Banino** investigates how satellites are being used to monitor $CO_2$ levels from space

Something big happened in 2020. According to the Global Carbon Project, carbon dioxide ($CO_2$) emissions declined by 2.4bn tonnes – the biggest drop ever recorded. It is a faint silver lining to a year of COVID-19 lockdowns, and a distraction from the longer-term trend – in 2019, $CO_2$ emissions hit a record high (36.8bn tonnes). Now, as restrictions ease thanks to vaccination programmes, $CO_2$ emissions are returning to pre-pandemic levels.

Nevertheless, 2021 could be a big year for cutting $CO_2$. After taking office in January, President Joe Biden reinstated America's commitment to the Paris Agreement, an international treaty on climate change. In April, Prime Minister Boris Johnson set new, more aggressive emissions reduction targets for the UK. In May, Germany brought its deadline to become carbon neutral forward to 2045. And further pledges to cut $CO_2$ may come in November's UN Climate Change Conference of the Parties (COP26).

But such pledges are meaningless unless action is taken to keep them. And how will we know if those actions are having an effect? More to the point, how do we know how much $CO_2$ there is in the atmosphere to begin with? Scientists, such as Dr Annmarie Eldering, can answer those questions with the help of $CO_2$-monitoring satellites.

## Rise to the challenge

Eldering has been involved in the task since NASA's Orbiting Carbon Observatory-2 (OCO-2) got the go-ahead in February 2010. She had joined NASA's Jet Propulsion Lab in the late 1990s to work on measuring air pollution from space. "It was a pretty small leap to go from air pollution to measuring $CO_2$," she says. "$CO_2$ is the most important of the gases humans emit for driving climate change. It's a really big problem, for us and the globe. It's something we've got to understand and start acting on. But measuring $CO_2$ from space is challenging."

Challenging is an understatement. Since 2016, the concentration of $CO_2$ in the atmosphere has been over 400 parts per million – a level unseen since the mid-Pliocene, 3 million years ago. But as high as that is, it's still a staggeringly difficult amount to keep track of. Imagine trying to account for 400 pennies scattered among one million coins of all denominations spread across a floor. ▸

The Mauna Loa Observatory in Hawaii monitors concentrations of $CO_2$ in Earth's atmosphere

▸ Now imagine that each day someone adds a few more pennies or takes a couple away. That's the challenge Eldering and the OCO-2 team took on.

They weren't starting from scratch, though. Thanks to Eunice Foote and John Tyndall's work in the 1850s, we know about the dangers of increasing concentrations of atmospheric $CO_2$, a greenhouse gas, on the climate. And since Charles David Keeling established a weather station on Hawaii's Mauna Loa volcano in 1958, we've been monitoring them.

But the Mauna Loa Observatory only gives us a tiny snapshot of the $CO_2$ in Earth's atmosphere. Even the global network of ground- and sea-based monitoring stations that has developed to support it can't provide a complete picture. And that's because Earth's atmosphere extends to around 10,000m above sea level, so most of it is nowhere near the monitoring equipment. Hence the need for $CO_2$-monitoring satellites.

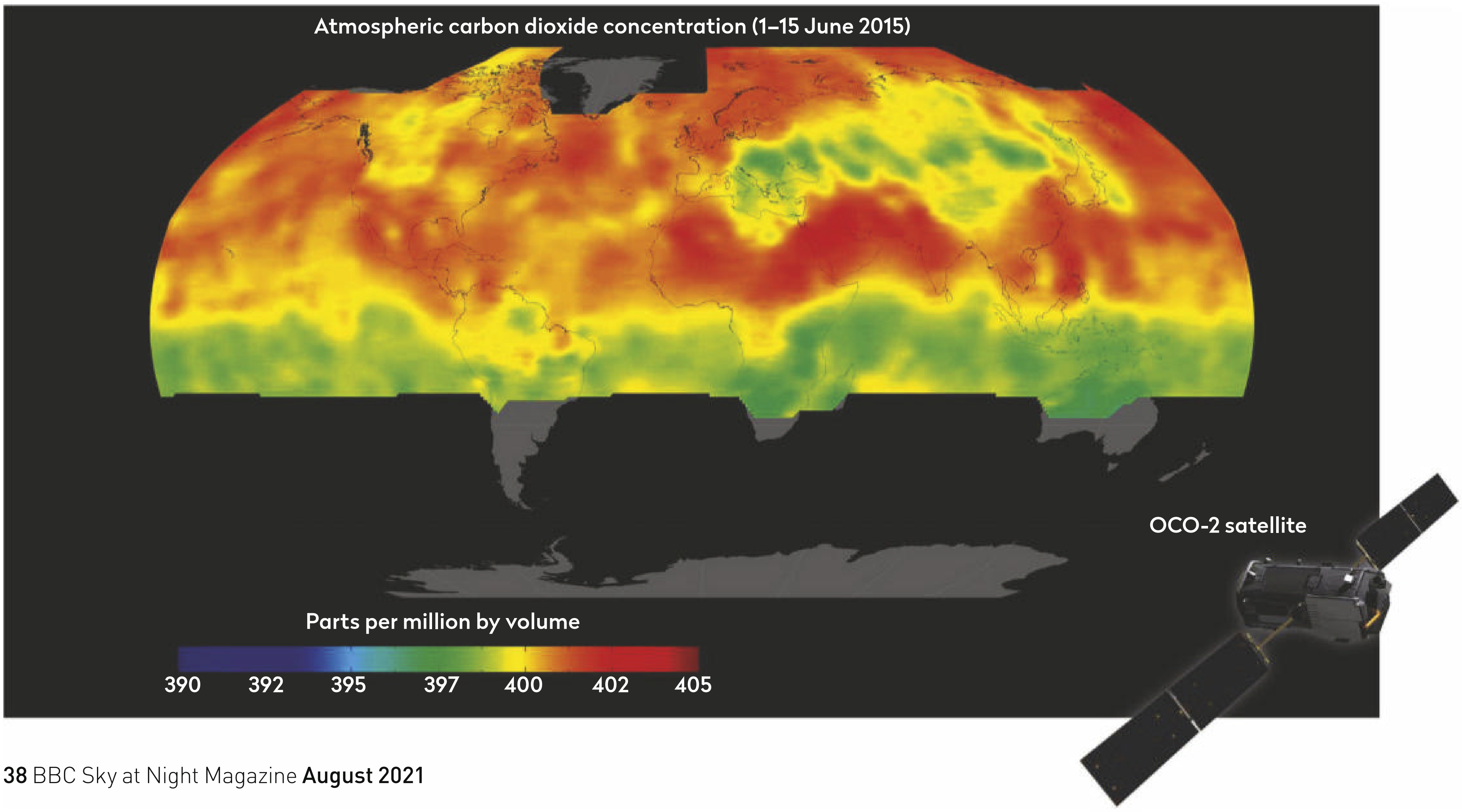
"The big motivation was to find out, on a global scale, how $CO_2$ moves between the atmosphere, the ocean and the land," says Eldering. "As a lot of our information came from ground- and ship-based measurements, there was a huge part of Earth we didn't observe."

## Watching from above

OCO-2 launched on 2 July 2014 and OCO-3 on 4 May 2019. Together, they help to keep track of the $CO_2$ in Earth's atmosphere. Fundamentally, they're the same – both carry an instrument containing spectrometers that measure wavelengths of sunlight that have reflected off Earth's surface and passed through the atmosphere.

"What's important about that is every gas [in the atmosphere] has a unique way of interacting with light," says Eldering. "[Each gas] absorbs a little bit of light as it passes through. So if you know the pattern of absorption for a particular gas and you've got a really precise measurement of the light; you can see that there were more molecules [of that gas] here than there were over there."

▼ Data from the OCO-2 satellite in June 2015, with higher concentrations of carbon dioxide shown in red and lower concentrations shown in yellow and green

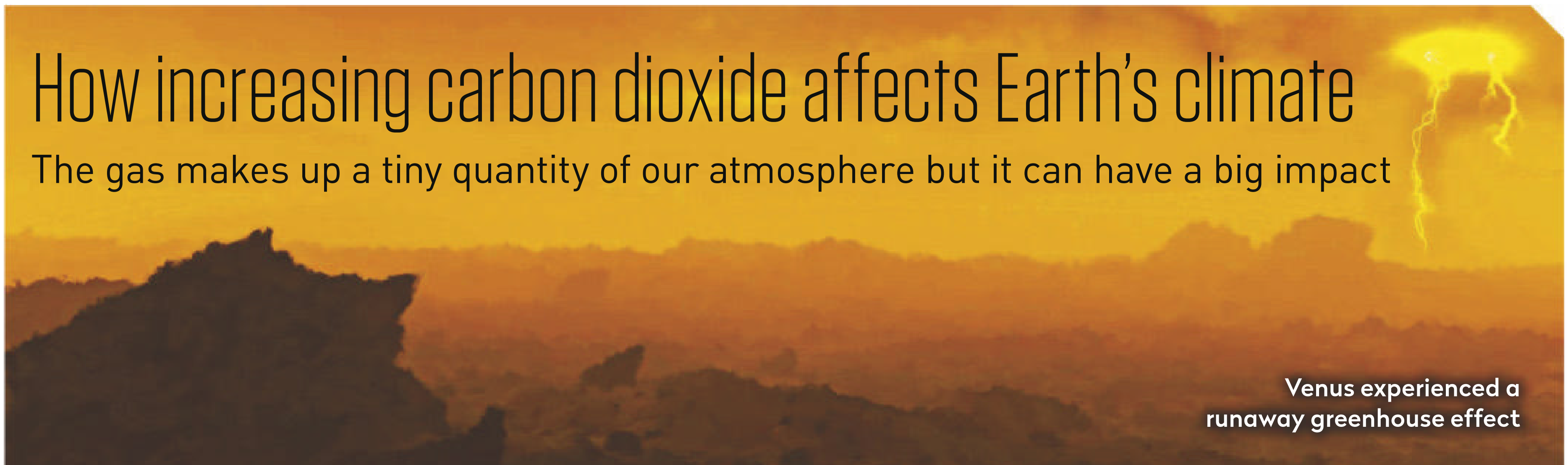



OCO-2 satellite

FRED ESPENAK/SCIENCE PHOTO LIBRARY, NASA/JPL-CALTECH X 2, SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO, RICHCAREY/ISTOCK/GETTY IMAGES

# How increasing carbon dioxide affects Earth's climate

## The gas makes up a tiny quantity of our atmosphere but it can have a big impact



**Venus experienced a runaway greenhouse effect**

Carbon dioxide ($CO_2$) accounts for just 0.04 per cent of Earth's atmosphere, so how can it have such a big effect on the planet's climate? Well, firstly, $CO_2$ traps heat (hence it's known as a greenhouse gas) and secondly, it remains in the atmosphere for centuries.

Earth receives huge quantities of energy from the Sun in the form of sunlight. As this is short-wave radiation, it passes through the atmosphere largely unhindered. Most of that energy is absorbed by the surface, but about 17 per cent is reflected back in the form of heat (long-wave, infrared radiation).

Infrared radiation effectively passes straight through oxygen and nitrogen (which comprise the vast majority of Earth's atmosphere), thanks to their relatively simple molecular structure. But the molecular structure of $CO_2$ is more complex, so it absorbs the infrared and heats up, then begins to radiate its heat to molecules nearby. The more $CO_2$ molecules there are, the more of that heat is absorbed, the hotter Earth's atmosphere becomes, and the greater the impact on Earth's climate.

Methane, another greenhouse gas, has an even more complex molecular structure than $CO_2$ so absorbs even more heat. But methane stays in the atmosphere for little more than a decade. $CO_2$ can hang around for anything from 300 to 1,000 years; hence the accumulation of it has a significant impact on our planet's heat balance.

For evidence of the effect greenhouse gases can have on a planet's climate, look no further than Venus. With a similar size and atmosphere to Earth early in its history, it was essentially Earth's twin until around 700 million years ago, when a runaway greenhouse effect took hold. Today, its atmosphere is 96 per cent $CO_2$ and its surface temperature is around 460°C – hot enough to melt lead.

ILLUSTRATION

With that information, scientists can see where $CO_2$ is accumulating and how it's influenced by temperature and pressure changes, climatic or geological events (such as El Niño events or volcanic eruptions), and even seasonal vegetation growth.

Where OCO-2 and OCO-3 differ is in what their instruments are attached to. OCO-2's is packaged into a satellite in heliosynchronous orbit; OCO-3's is mounted on the International Space Station (ISS). What that means is OCO-2 orbits the poles at an altitude of 700km, passing over any given spot at the same time (guaranteeing it's in sunlight). Meanwhile, OCO-3 orbits with the ISS, about 400km above Earth, and sees different locations at different times.

**▼ As forests continue to be cleared, natural carbon sinks that absorb $CO_2$ are destroyed**

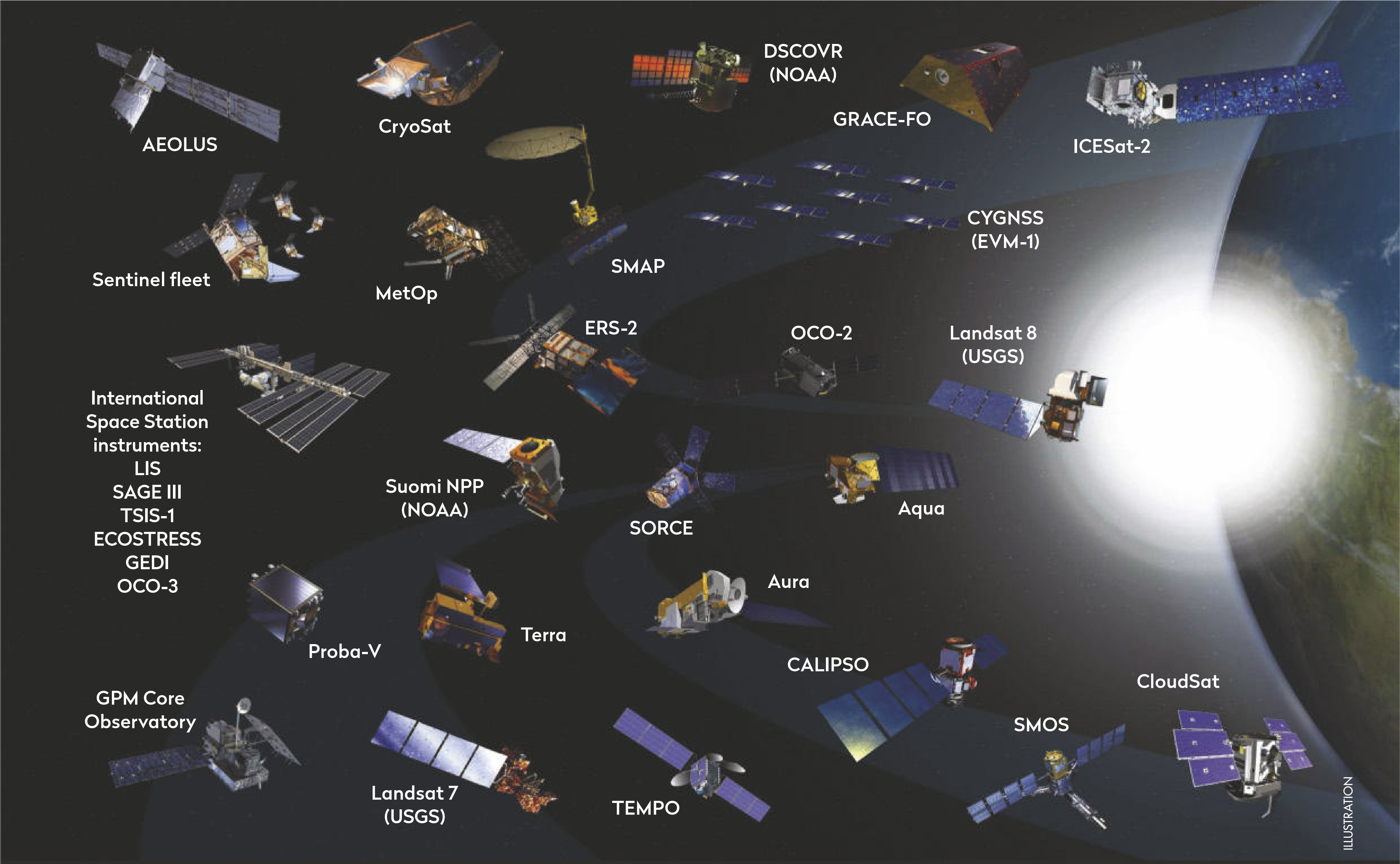
## Out of balance

There has always been, and always should be, some $CO_2$ in Earth's atmosphere because every living thing emits $CO_2$, either through respiration while it's alive or decomposition once it's dead. But those emissions are balanced by the $CO_2$ absorbed by photosynthesis and colder parts of the oceans.

The problem is that $CO_2$ emissions from human activity – anthropogenic emissions – have unbalanced that natural cycle. Ever since we began burning fossil fuels (oil, coal and natural gas) we've essentially been digging up $CO_2$ that had been removed from the cycle and pumping it into the atmosphere. But we've failed to balance those emissions by creating new sinks to absorb that extra $CO_2$.

To make matters worse, by clearing vast areas of rainforest across the tropics, we've also decreased the capacity of Earth's natural $CO_2$ sinks, leaving us staring down the barrel of catastrophe. Without taking action to reduce our $CO_2$ emissions, we're facing climate disaster.

The trouble is, we can't tell if those actions are helping without knowing how much $CO_2$ we're responsible for. We need to differentiate between natural and anthropogenic $CO_2$, and that's even harder than monitoring $CO_2$ from space. To return to the coin analogy, it's akin to determining how many of those 400 pennies are real and how many ►




▲ A fleet of Earth-monitoring satellites are currently in orbit, with more joining them to assess $CO_2$ levels

# Monitoring Earth's climate

Some of the key missions helping to keep track of the planet's vital stats across land, air and sea

**TEMPO, NASA & Smithsonian Astrophysical Observatory**
The Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument will fly aboard a commercial satellite and measure the daily variations in air quality over North America. Expected to launch in 2022, it will assess concentrations of ozone, nitrogen dioxide, sulphur dioxide and other chemicals from a geostationary orbit to track emissions and improve air-quality forecasts.

**GRACE-FO, NASA & German Research Centre for Geosciences**
The Gravity Recovery and Climate Experiment Follow-On mission is a pair of satellites launched in 2018 to monitor Earth's water. GRACE-FO picks up where GRACE left off, providing an indication of climate variability by measuring small changes in the planet's gravity field that correspond to the amount of water in lakes, rivers, oceans, ice sheets and the ground.

**Copernicus Sentinel fleet, ESA**
Europe's growing stable of Earth-monitoring satellites currently comprises six missions (Sentinel-1, -2, -3, -4, -5P and -6), but will grow over the coming years with the launches of Sentinel 5 and further expansion missions, including OCO-2. Monitoring everything from soil moisture, water quality and land cover to surface temperature, sea level, air quality and pollution, they provide key information on Earth's changing climate.

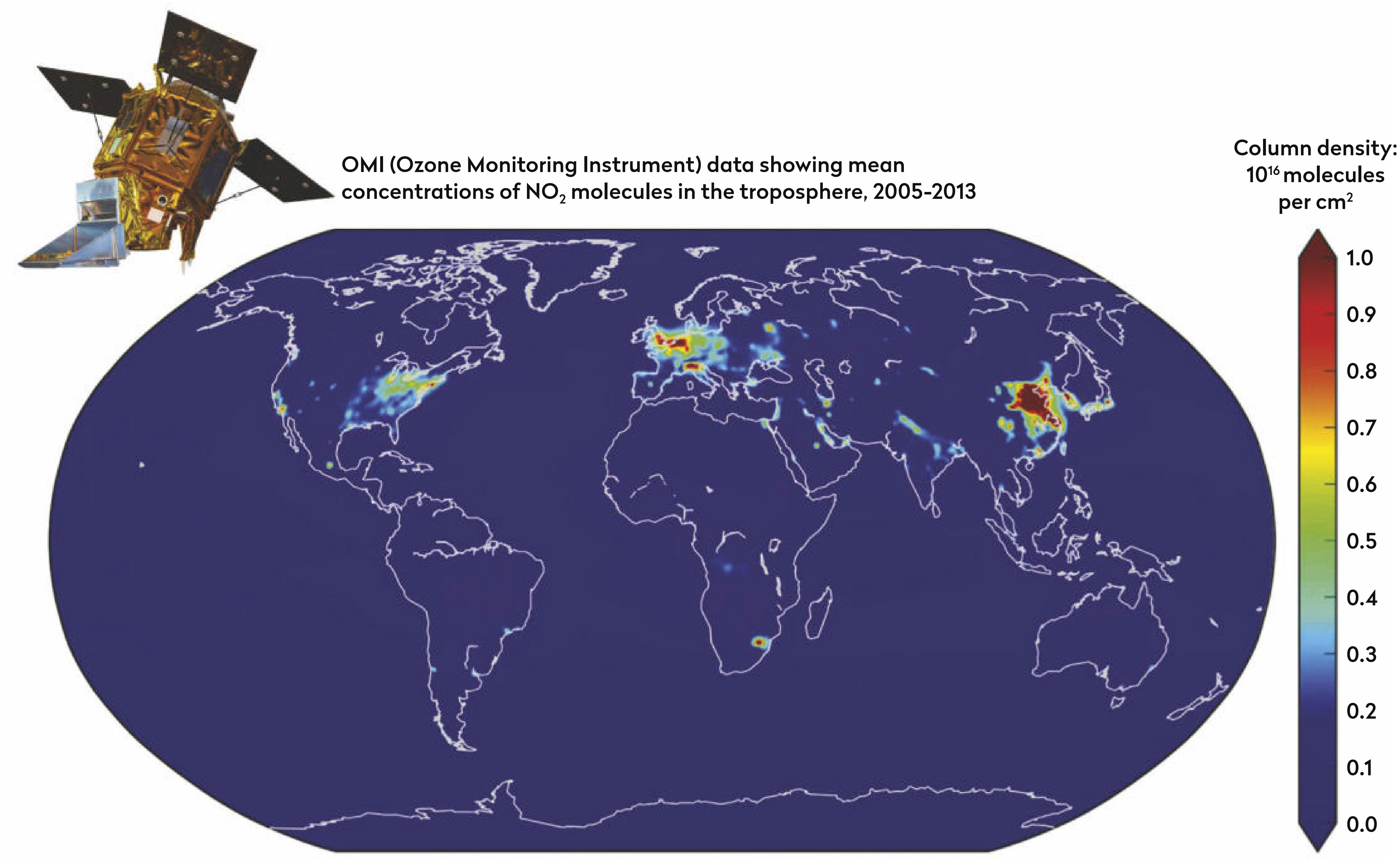
**Suomi NPP, NASA**
Launched in 2011, the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite collects a range of data to improve weather forecasting and provide insights into climate change. It has five instruments that monitor changes in vegetation productivity, atmospheric ozone, sea and land surface temperatures, as well as monitoring glaciers, sea ice, land ice and natural disasters around the world.

► are counterfeit. It's difficult, but not impossible, provided you have a device that can measure nitrogen dioxide ($NO_2$) levels. And that's where the TROPOspheric Monitoring Instrument (TROPOMI) comes in.

## A combined approach

TROPOMI examines Earth's atmosphere, while orbiting aboard the Copernicus Sentinel-5P satellite. It was built by the European Space Agency (ESA) and the Netherlands Space Office, to measure, among other things, nitrogen dioxide ($NO_2$). "$NO_2$ is one of the keys to differentiating natural carbon emissions from anthropogenic ones," says Eldering. "$NO_2$ comes from burning fuels, an anthropogenic source. So we've been testing the idea of combining OCO-3 and TROPOMI data."

Combining that data gives you a pretty reliable indication of the origin of the $CO_2$. Broadly speaking, if the data shows $CO_2$ alone, it's probably a natural




**▲ Data on nitrogen oxide ($NO_2$) levels gathered by the TROPOMI instrument – on board the Copernicus Sentinel-5P satellite (inset) – can be combined with $CO_2$ data to help differentiate between natural and anthropogenic emissions. The above data shows $NO_2$ levels in the troposphere – the lowest layer of Earth's atmosphere – as monitored by the OMI (Ozone Monitoring Instrument) on NASA's Aura satellite**

emission, but if $CO_2$ is present with $NO_2$, chances are it's anthropogenic.

The tests have proved successful. So successful that a European consortium is developing a system that uses this approach to evaluate the attempts by cities, countries and industries to reduce their $CO_2$ emissions. And the European Union's Copernicus Earth Observation programme is preparing a constellation of three satellites scheduled to launch in 2025 that will play a key role in our bid to hit the emission reduction targets of the Paris Agreement.

"The whole idea is that, if we're serious about taking action [to mitigate climate change], we need to be able to monitor the impact of those actions," explains Dr Richard Engelen, the Deputy Director of the Copernicus Atmospheric Monitoring Service (CAMS). "We need direct feedback on how well they result in reduced $CO_2$ concentrations in the atmosphere."

## Support network

For that feedback to be useful it has to distinguish between natural and anthropogenic $CO_2$. The Copernicus satellites, with their ground- and sea-based support network, can do this.

"We try to combine as much information as possible from different sources, so not just [satellite] observations, but also all we already know about fossil fuel emissions," says Engelen. "We know where power plants are, for instance, we know where the big cities are and we have some knowledge about the variability of the emissions, in terms of energy consumption. We'll use all of that and combine it to come to the best estimates of the emissions."

The Copernicus $CO_2$ emission-monitoring service isn't just another batch of satellites carrying spectrometers; it's a big step forward in terms of coverage and precision. The Copernicus satellites will be able to cover Earth's surface faster and in greater detail, giving us our clearest indication yet of how much $CO_2$ is in the atmosphere and where it came from.

"Being able to extract the anthropogenic signal from all the natural variability we see – this is really a challenge and where we're working on top of our scientific ability," says Engelen.

"It's still very much in the development phase and we're aiming to have an operational service by 2026. That's because within the Paris Agreement, countries have agreed on a global stocktake process where they report on the results of their actions [to reduce emissions] every five years. The first is in 2023, reporting on the [years since the rules were adopted in 2018]. But the next one is in 2028… so we want Copernicus to be ready for that, which gives us a few years to build the new service. But it's quite a large undertaking."

It's a large undertaking however you look at it. Large in terms of ambition. Large in terms of the number of organisations behind it – CAMS, implemented by the European Centre for Medium-Range Weather Forecasts, will handle the satellites' data, but it'll be ESA that builds and launches them, and EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites, that operates them. But, most of all, as Engelen explains, it's large in terms of purpose.

"You have to see it as part of the global effort to reduce emissions. We want to know how successful these efforts are but, as we're working within a global agreement, all the countries need to be able to trust each other. [Copernicus] will help to build more of that trust. The advantage of using satellite observations is that it provides a much more consistent view of emissions globally than we would get from individual approaches."

**Rob Banino** is a freelance science writer and journalist

BOXOUT ILLUSTRATION BY PAUL WOOTTON, WWW.TROPOMI.EU/ESA, ESA/ATG MEDIALAB

16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

# The Sky Guide

AUGUST 2021

## A MONTH OF METEORS

Enjoy a promising Perseid peak on 12 August and an Aurigids outburst at the end of the month

## DOUBLE THE VIEW

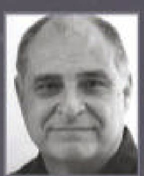
Observe Jupiter and Saturn, both at opposition in August

## FIND THE 'ZENO STEPS'

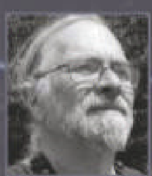
Discover one of the Moon's lesser-known clair-obscur effects

PETE LAWRENCE

### About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



**Steve Tonkin** is a binocular observer. Find his tour of the best sights for both eyes on page 54

### Also on view this month…

- ✦ Jupiter's double moon and shadow transits
- ✦ Delaunay, the Moon's misshapen crater
- ✦ Meteor trains, and how to observe them

### Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

### Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyat nightmagazine.com**

# AUGUST HIGHLIGHTS

Your guide to the night sky this month

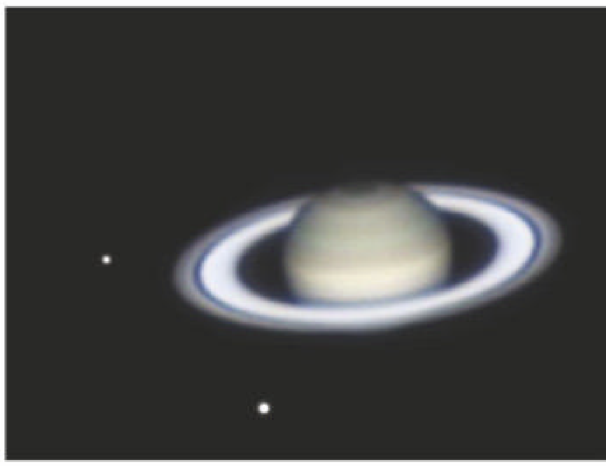
## Sunday ▶

**1** An unusual occultation of Europa by Ganymede occurs at 23:00 BST (22:00 UT) this evening. The relative motion of both moons means that Ganymede appears to cover part of Europa, which then appears to pull away again. See page 47 for more details.

## Monday ▶

**2** Saturn is at opposition today. A phenomenon known as the 'opposition effect' causes the planet's rings to brighten and this should be noticeable through a telescope.

This morning's 35%-lit waning crescent Moon sits 6.7˚ south of the Pleiades.



## ◀ Thursday

**5** As this morning's 12%-lit waning crescent Moon rises, it'll be passing over the northern portion of open cluster M35. The event concludes around 02:40 BST (01:40 UT).

## Tuesday

**10** This evening and tomorrow evening, the waxing crescent Moon – visible shortly after sunset – will be close to the mag. –3.9 planet Venus.

## Wednesday

**18** Mag. –0.41 Mercury lies low above the western horizon shortly after sunset. Not so obvious is mag. +1.8 Mars, just 20 arcminutes east of Mercury this evening, the bright evening twilight making it a challenge to see.

## Thursday

**19** Jupiter is at opposition today. A telescope view of the gas giant as it approaches the west-southwest horizon will show the moons Io and Ganymede just 2 arcseconds apart at 05:15 BST (04:15 UT). See page 47 for more.

## Friday

**20** Starting at 02:50 BST (01:50 UT), Io and its shadow will begin to cross Jupiter's disc. As this is close to Jupiter's opposition and we're just past Jupiter's equinox, the satellite's body will overlap its shadow. More on page 47.

## Saturday

**21** This evening's full Moon represents the Moon at opposition.

This evening between 21:15 BST (20:15 UT) and 23:35 BST (22:35 UT) Io and its shadow will transit Jupiter's disc. See page 47.

## Family stargazing

Observing a favourable appearance of the Perseid meteor shower can be a summer-holiday treat that will be remembered for a long time. Dealing with a night observation can be tricky for youngsters, so schedule sleep from early evening to midnight BST on 12 August. Then go out and meteor watch (see page 46) until 03:30 BST (02:30 UT) on the 13th. A sun lounger with a sleeping bag creates a warm platform to observe from. In the quiet periods between meteors, you can identify some of the stars and constellations with our all-sky chart on page 50. **www.bbc.co.uk/cbeebies/shows/stargazing**

## Tuesday

**24** A telescopic view of the morning Moon at 04:30 BST (03:30 UT) will show a less common clair-obscur effect known as the 'Zeno Steps', which is caused when the evening terminator is near the 18km-crater Zeno E on the lunar northeast limb.

## Monday

**30** Io and Ganymede transit Jupiter's disc, accompanied by their shadows. The event starts at 21:00 BST (20:00 UT) with Io starting to transit, and ends at 04:22 BST (03:22 UT) as Ganymede's shadow slips off Jupiter's disc. See page 47.

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## Tuesday ▶

**3** This morning's 26%-lit waning crescent Moon sits 4.8˚ north of mag. +0.8 Aldebaran (Alpha (α) Tauri).

## Saturday

**7** There's a chance to catch a slender 2%-lit waning crescent Moon low above the northeast horizon from just after 04:00 BST (03:00 UT).

Jupiter's outer Galilean moon, Callisto, is eclipsed by Jupiter's shadow this morning. Watch the moon disappear at 03:22 BST (02:22 UT). To read more, see page 47.

## Monday

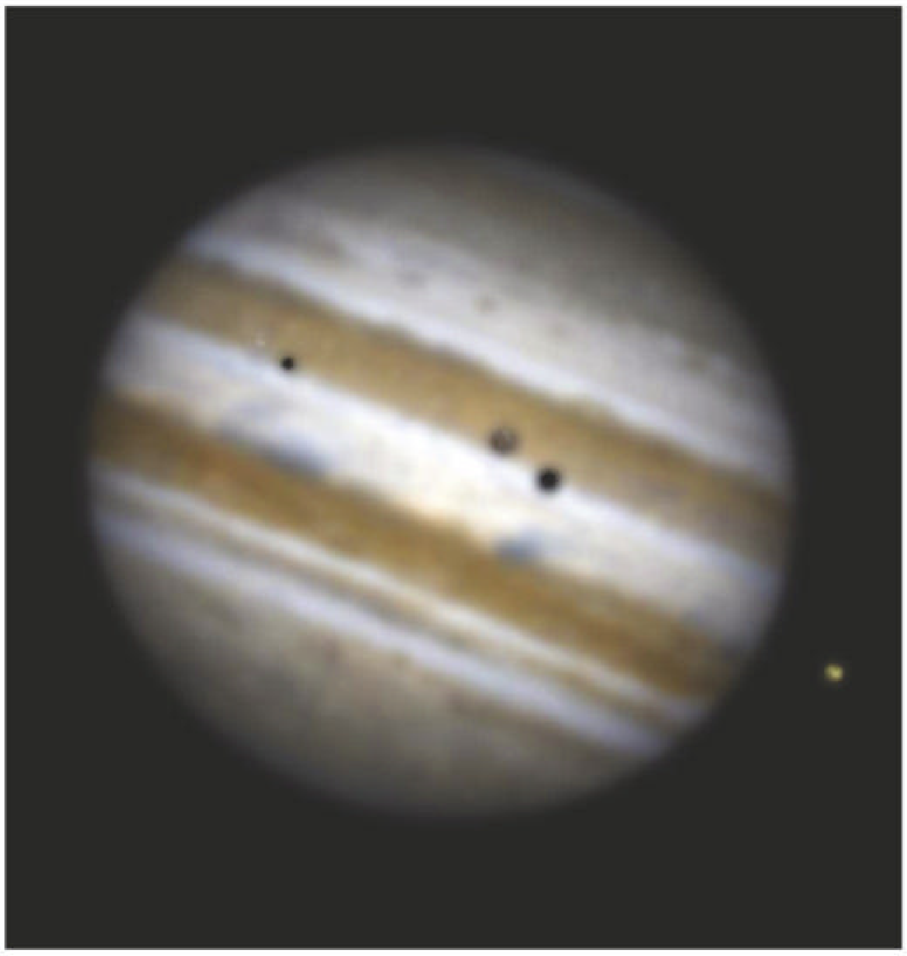
**9** This morning, a telescopic view of Jupiter will show its second Galilean moon, Europa, virtually disappear as it's covered by Ganymede's shadow. The eclipse takes place between 04:37–05:44 BST (03:37–04:44 UT). To read more see page 47.

## Thursday

**12** The Perseid meteor shower reaches its peak under favourable conditions. The peak is centred on 20:00–23:00 BST (19:00–22:00 UT) so tonight's watch, through to dawn on the 13th, will see the best rates. To read more, see page 46.

## Sunday ▶

**22** This evening, take a look at Jupiter to see a double bonanza: two moons (Ganymede and Europa) in transit at the same time as their shadows are in transit. The event is underway as Jupiter rises. See page 47 for more details.



## Tuesday

**31** The lesser-known Aurigid meteor shower could produce an activity outburst between 22:17–22:35 BST (21:17–21:35 UT). Rates may increase to produce a ZHR with a range of 50 to 100 meteors per hour. See page 47.

# NEED TO KNOW

The terms and symbols used in The Sky Guide

**Universal time (UT) and British Summer Time (BST)**
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

**RA (Right ascension) and dec. (declination)**
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

**Family friendly**
Objects marked with this icon are perfect for showing to children

**Naked eye**
Allow 20 minutes for your eyes to become dark-adapted

**Photo opp**
Use a CCD, planetary camera or standard DSLR

**Binoculars**
10x50 recommended

**Small/ medium scope**
Reflector/SCT under 6 inches, refractor under 4 inches

**Large scope**
Reflector/SCT over 6 inches, refractor over 4 inches

## GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

## DON'T MISS

# SPECTACULAR PERSEIDS

**BEST TIME TO SEE:** 8–16 August, peak night 12/13 August

Everything's falling into place for a potentially spectacular display of Perseid meteors this month. Generally, low-rate activity occurs between 17 July and 24 August with the exception of the peak period 8-16 August, a sharp peak typically seen around 11–13 August. The peak timing varies year on year. In 2021 it's predicted for 20:00-23:00 BST (19:00-22:00 UT) on 12 August. Rates naturally increase after local (non-daylight saving time) midnight, so the period from 01:00-03:30 BST on the 13th is optimal.

The Perseid shower is a solid performer, reaching a peak zenithal hourly rate (ZHR) of 100-plus meteors per hour. This is what you'd see under perfect viewing conditions with the meteor radiant overhead and the ability to see the whole sky. However, the actual visual hourly rate is often lower.

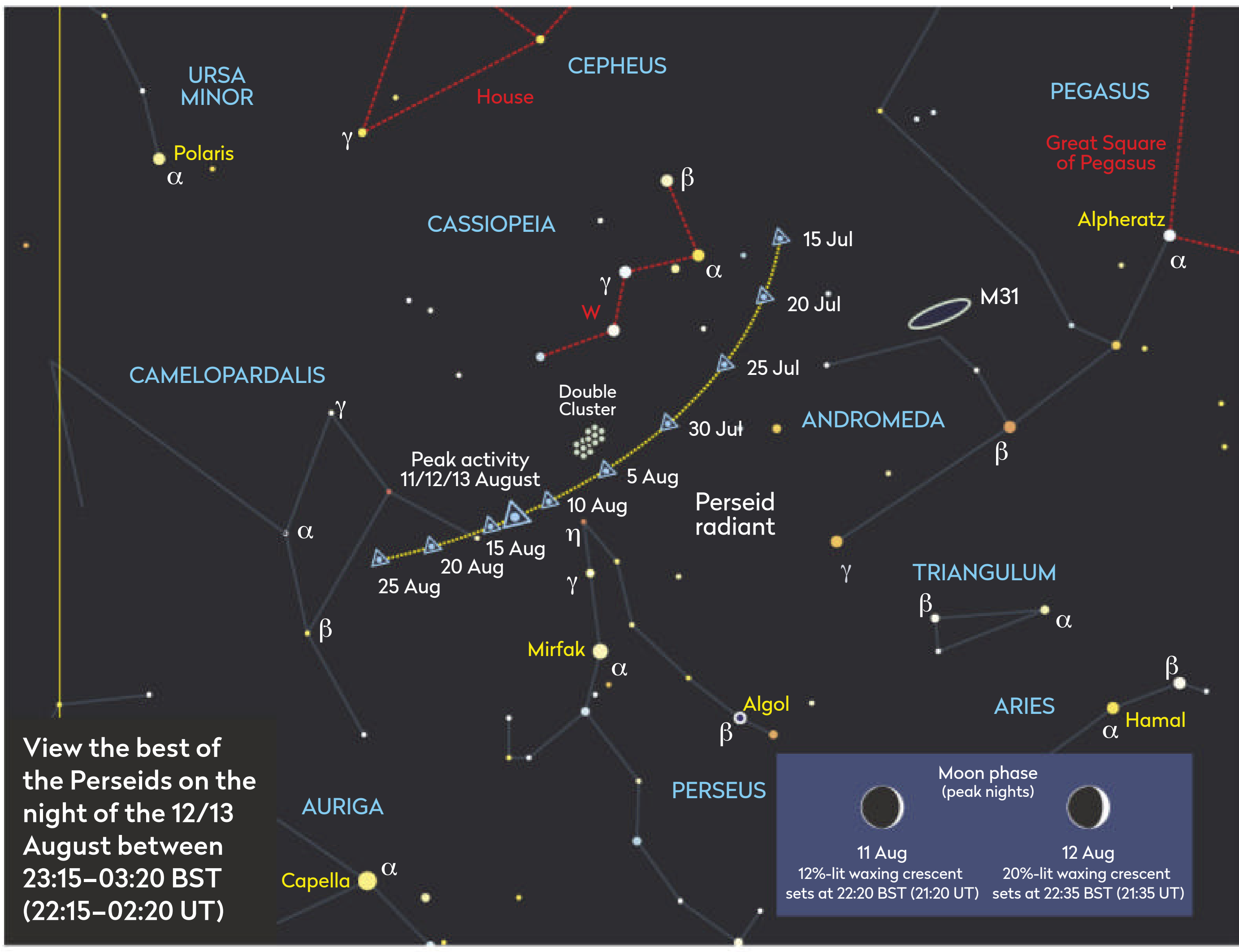
Two variable factors affect shower visibility; the weather and the Moon. There's little you can do about the weather except move location if things look really bad. The Moon either interferes or it doesn't. On 12 August, the 4.5-day old, 20%-lit waxing crescent Moon sets at 22:35 BST (21:35 UT) and won't interfere.

Meteor showers occur when Earth passes through dust distributed around a comet's orbit. Entering our atmosphere on parallel paths, perspective causes meteor trails to appear to emanate from the same sky location – the shower radiant. Over the activity period, the radiant's position drifts against the background stars. Peak activity represents us passing through the densest part of the stream.

A garden lounger is a great viewing platform. Look for meteors at an altitude around 60° in any direction. While longest trails are seen 40–140° from the radiant, towards the radiant expect short trails. A look in the opposite direction to the radiant will reveal trails that appear short and converge to a point called the anti-radiant.

Perseid displays often exhibit bright events, many of which show what appears to be an after image of the trail, which is a weakly glowing column of ionised gas. This 'meteor train' fades from view as the energy in the ionised atoms is given up. High altitude winds may also affect the train, distorting its shape.

▸ **See the 'Perseid Perfection' feature on page 28 for more on this year's shower**



View the best of the Perseids on the night of the 12/13 August between 23:15–03:20 BST (22:15–02:20 UT)


Make sure your eyes are properly dark adapted from around 22:30 UT (21:30 BST) on 12 August

ALL PICTURES: PETE LAWRENCE

# Ganymede occults Europa

**BEST TIME TO SEE:** As specified

Jupiter reaches opposition on 19 August and there are a number of fascinating events visible involving its four largest 'Galilean' moons. On 1 August, Ganymede partially occults Europa from 23:00 BST (22:00 UT). Then on the 7th, the outer moon Callisto is eclipsed by Jupiter's shadow from 03:22 BST (02:22 UT).

On the 9th, Europa virtually disappears as it's eclipsed by Ganymede's shadow between 04:37–05:44 BST (03:37–04:44 UT). Smaller scopes will show Europa dimming out of view for a short time.

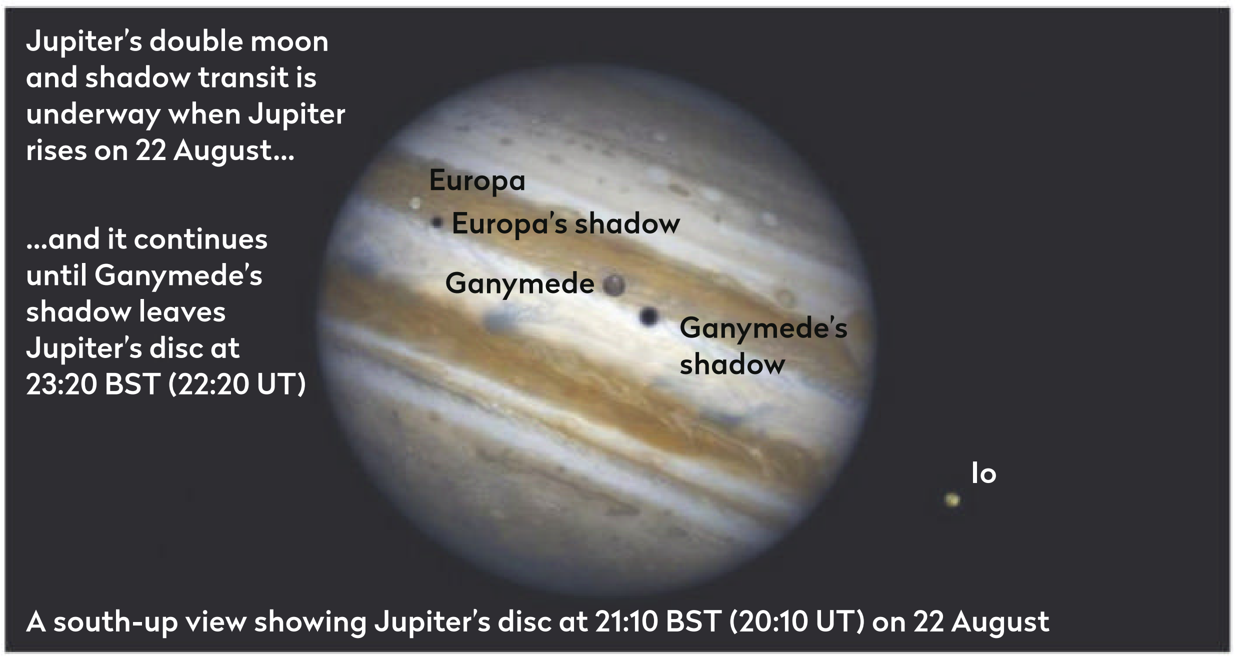
At opposition on 19 August, Io and Ganymede will appear close as Jupiter approaches the west-southwest horizon in the morning sky; at 05:15 BST (04:15 UT) they appear just 2 arcseconds apart.

On 20 August, starting at 02:50 BST (01:50 UT), Io and its shadow begin to transit Jupiter's disc. Being near opposition and as we're just past a Jovian equinox (2 May), Io and its shadow almost line up on Jupiter's disc. Both appear central on the disc at 04:00 BST (03:00 UT), the transit concluding at 05:10 BST (04:10 UT).

The opposition moon–shadow alignment doesn't last long and on the evening of 21 August between 21:15-23:35 BST (20:15-22:35 UT) Io transits with its shadow now notably out of sync.

On the 22nd, an evening view of Jupiter through a telescope will show Europa and Ganymede in transit at the same time as their shadows. The event is underway as Jupiter rises, ending at 23:20 BST (22:20 UT) as Ganymede's shadow transit ends.

On the 29th, Europa and Ganymede transit Jupiter again accompanied by their shadows. The fit isn't quite as good as the event on the 22nd as it's not possible to see all four entities on the disc at the same time. It starts at 21:00 BST (20:00 UT) and ends at 03:20 BST (02:20 UT) on the 30th.



A south-up view showing Jupiter's disc at 21:10 BST (20:10 UT) on 22 August

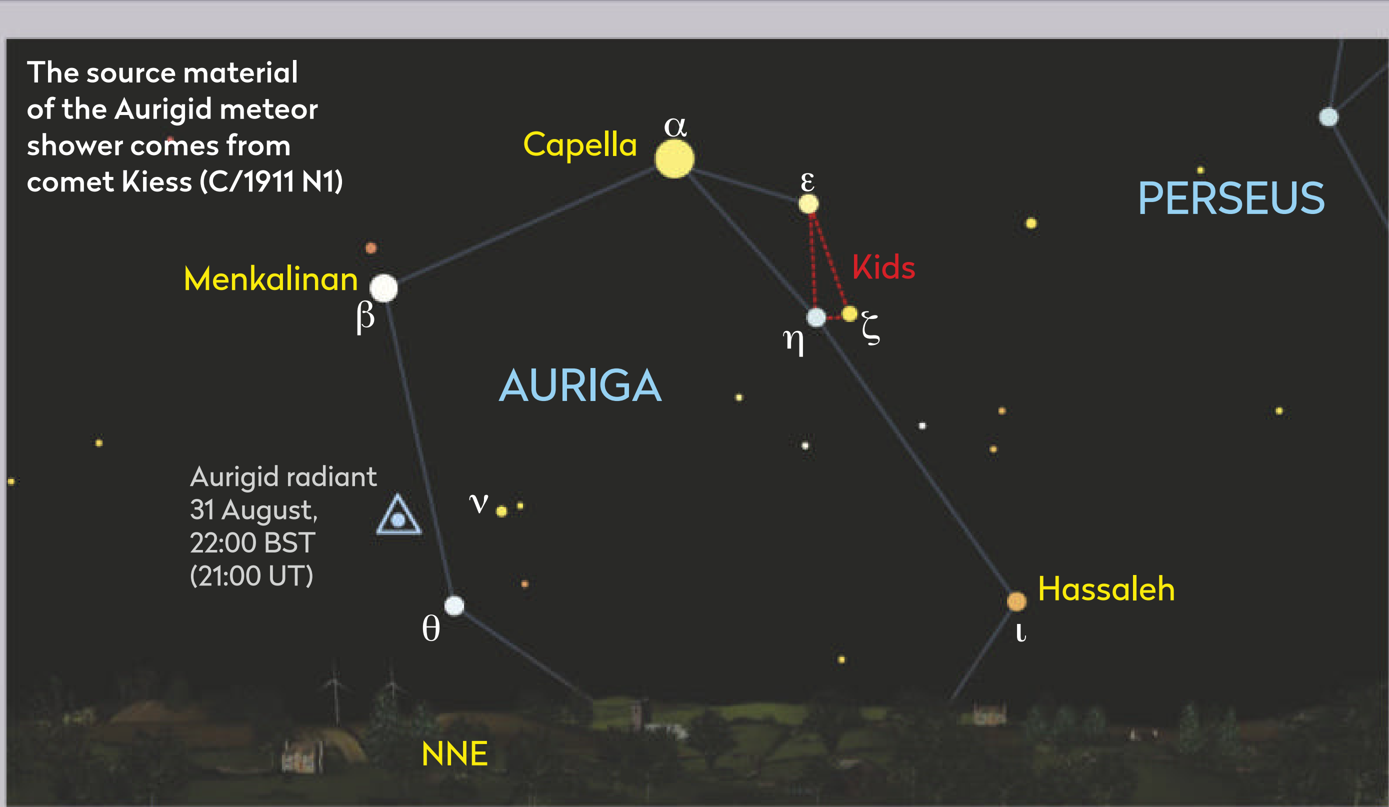
# The Aurigids

**BEST TIME TO SEE:**
**31 August, 22:00–23:00 BST (21:00–22:00 UT)**

Although the Perseid shower steals the limelight, there are many lower rate showers active at this time of year too. Active between 28 August and 5 September, the low-rate Aurigid shower has produced interesting activity outbursts in the past.

On 31 August between 22:17–22:35 BST (21:17–21:35 UT) an alert has been issued for possible enhanced Aurigid activity. Typically exhibiting a ZHR (zenithal hourly rate) of 6 meteors per hour, this might rise to between 50–100 meteors per hour. Bear in mind that the window of enhanced activity is short and a visual hourly rate is often lower than the quoted ZHR. Even so, a few recorded trails from the shower will make valuable observational evidence that the enhanced activity actually took place.

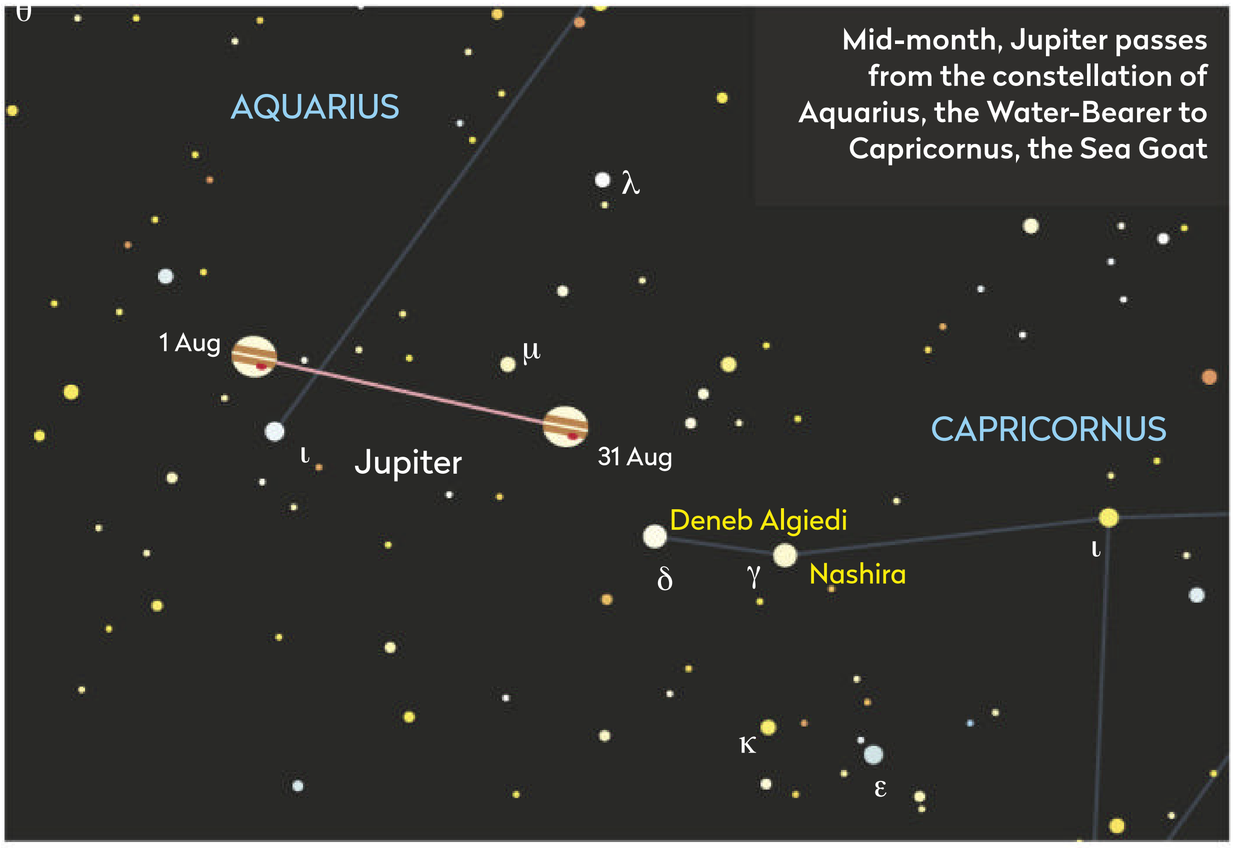
During the enhancement window the Moon will be a 35%-lit waning crescent and won't rise until 23:44 BST (22:44 UT). The radiant is located in the constellation of Auriga, the Charioteer, close to mag. +2.6 Theta (θ) Aurigae. Unfortunately, this will be low at 22:17 BST (21:17 UT), barely scraping the northern horizon. This will have an adverse effect on the number of trails seen, reducing the visual rate.



PICK OF THE MONTH

# Jupiter

**Best time to see:** 19 August, 01:22 BST (00:22 UT)
**Altitude:** 23.5°
**Location:** Capricornus
**Direction:** South
**Features:** Detailed atmosphere, Great Red Spot, moons
**Recommended equipment:** 75mm or larger




Mid-month, Jupiter passes from the constellation of Aquarius, the Water-Bearer to Capricornus, the Sea Goat

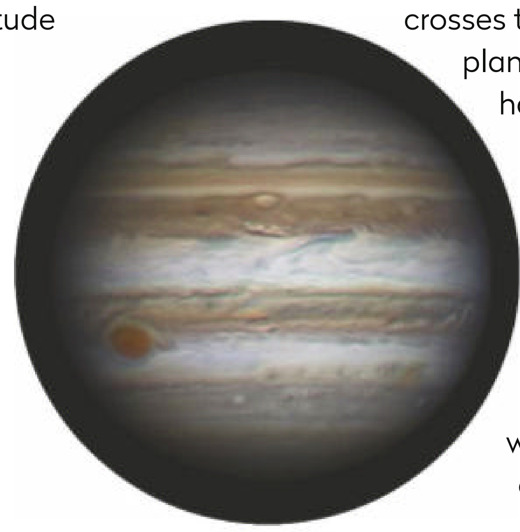
Jupiter reaches opposition on 19 August, the planet managing to attain a peak altitude of 23.5° in true darkness, due south, at 01:22 BST (00:22 UT). Full Moon, technically the Moon at opposition, appears 6.3° south-southwest of Jupiter on the night of 22 August.

Opposition describes a position in the opposite part of the sky to the Sun. At such times, planets appear brighter and larger than at other, non-opposition, times. In Jupiter's case, at opposition it shines at mag. –2.9 and through the eyepiece of a telescope has an apparent diameter of 49 arcseconds, large enough to present some impressive detail.

Over the past years, Jupiter has been low as seen from the UK, as it tracked along the most southerly part of the ecliptic. This is now slowly changing, and the planet is gaining altitude with each passing year. At opposition it's in Capricornus, but right on the constellation's eastern border with Aquarius. Technically, it starts the month in Aquarius, tracking west slightly through the month, crossing the Aquarius–Capricornus border to be within Capricornus on 19 August.

Jupiter reached equinox in early May and we can see a consequence of this on the morning of the 20th. At equinox, the Sun crosses the planet's equatorial plane. The Galilean moons have orbits closely aligned to this plane, and Io will transit Jupiter's disc on 20 August from 02:50 BST (01:50 UT) until 05:08 BST (04:08 UT).

Near opposition, Io's shadow virtually lines up with the moon in terms of Jovian longitude. The proximity to equinox makes the shadow virtually line up in latitude as well. A similar Io transit occurs on 21 August between 21:18 BST (20:18 UT) and 23:33 BST (22:33 UT).

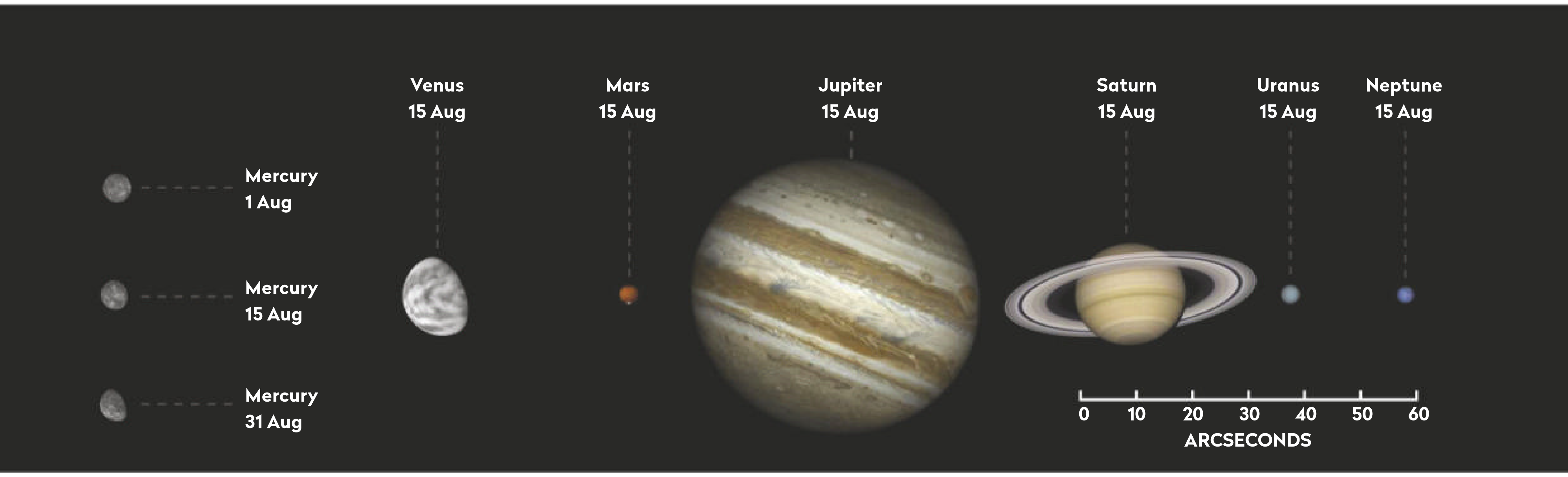


▲ As Jupiter reaches opposition on 19 August, a view through a scope will reveal plenty of detail

PETE LAWRENCE X 3

## The planets in August

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



## Mercury

**Best time to see:** 15 August, 20 minutes after sunset
**Altitude:** 1.5˚ (very low)
**Location:** Leo
**Direction:** West-northwest

Observing Mercury with the naked eye is possible this month, although the feat requires you to consider a celestial balancing act. Mercury reaches superior conjunction on the 1st, after which it returns to the evening sky. Its position is favourable and it's bright at the month's start. On the 6th, shining at mag. –1.4, it is visible above the west-northwest horizon for 25 minutes after sunset. On 9 August, at mag. –1.1, a 1%-lit waxing crescent Moon lies 7˚ to the east of the planet.

As we head through August, Mercury gets fainter but its time above the horizon increases slightly.

## Venus

**Best time to see:** 1 August, 30 minutes after sunset
**Altitude:** 6˚ (low)
**Location:** Leo
**Direction:** West

Venus is a poorly positioned evening planet, setting 68 minutes after the Sun on the 1st and 60 minutes after on the 31st. A 5%-lit waxing crescent Moon lies nearby on the 10th and as a 12%-lit crescent on the 11th. The visibility of Venus will be helped by its brilliance. During August it shines at mag. –4.0.

## Mars

**Best time to see:** 18 August, 20 minutes after sunset, near Mercury
**Altitude:** 1.5˚ (very low)
**Location:** Leo
**Direction:** West

Mars isn't a viable target as it's dim at mag. +1.8, small at less than 4 arcseconds across when viewed through a scope, and too low to appear against a darkened sky.

## Saturn

**Best time to see:** 2 August, from 01:00 BST (00:00 UT)
**Altitude:** 18.5˚
**Location:** Capricornus
**Direction:** South

Saturn is at opposition on 2 August, a time when it's in the opposite part of the sky to the Sun and visible all night under dark skies. Using a scope, look out for Saturn's rings appearing brighter than normal at opposition, dimming back to normal brightness over the following days. On the 2nd, mag. +0.4 Saturn sits due south at 01:15 BST (00:15 UT) and attains an altitude of 18.5˚.

## Uranus

**Best time to see:** 31 August, 04:00 BST (03:00 UT)
**Altitude:** 9˚
**Location:** Aries
**Direction:** Just east of south

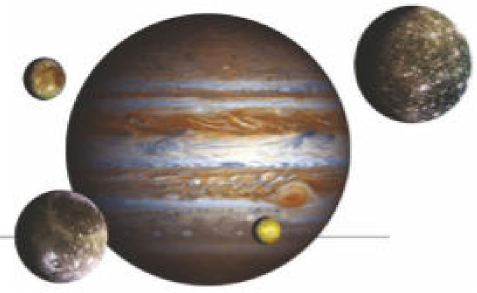
Morning planet Uranus improves in visibility this month. The mag. +5.7 planet reaches an altitude of 22˚ in darkness on the 1st, while on the 31st it manages an altitude of 49˚ at the end of darkness, falling just short of its highest point in the sky when due south.

## Neptune

**Best time to see:** 31 August, from 02:00 BST (01:00 UT)
**Altitude:** 33˚
**Location:** Aquarius
**Direction:** South

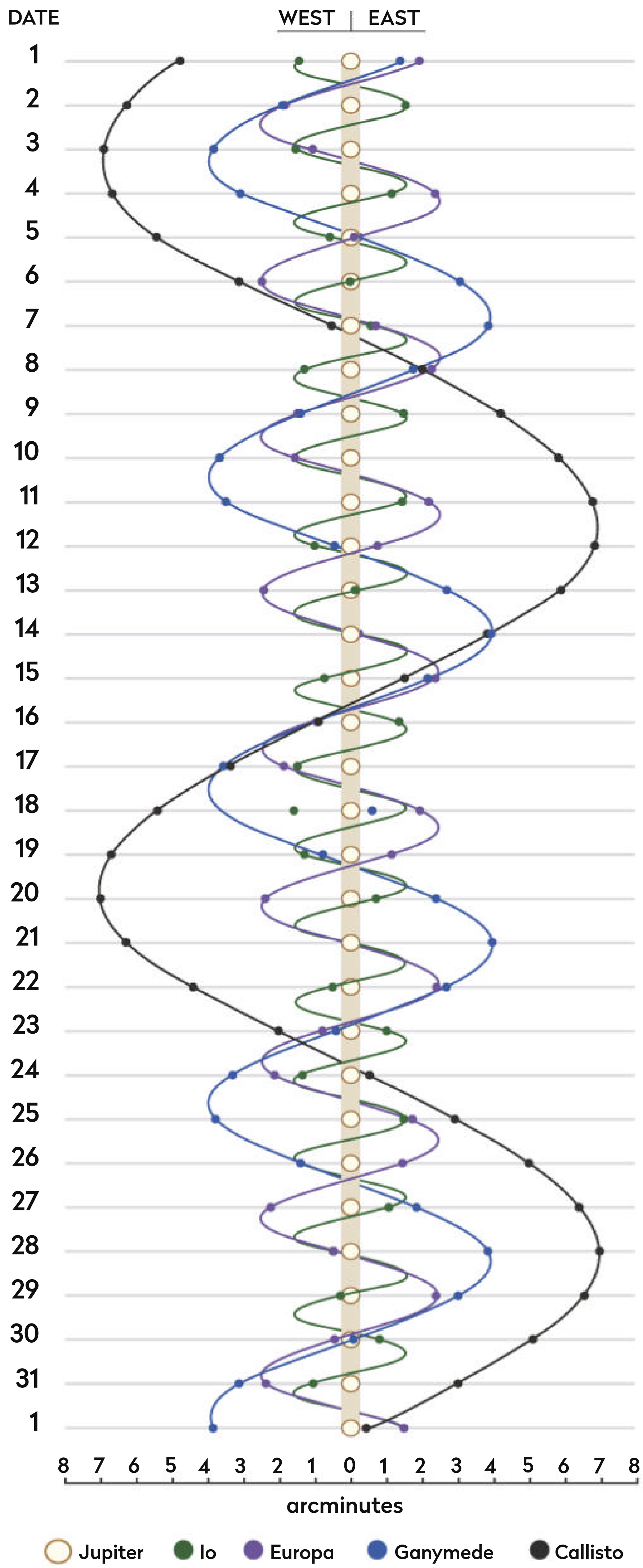
A month from opposition, morning planet Neptune's position improves over August and by mid-month it reaches its highest point in the sky, 33˚ up, under dark-sky conditions. At mag. +7.8 you'll need binoculars to spot Neptune.

More **ONLINE**
Print out observing forms for recording planetary events



## JUPITER'S MOONS: AUGUST

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



# THE NIGHT SKY – AUGUST

Explore the celestial sphere with our Northern Hemisphere all-sky chart

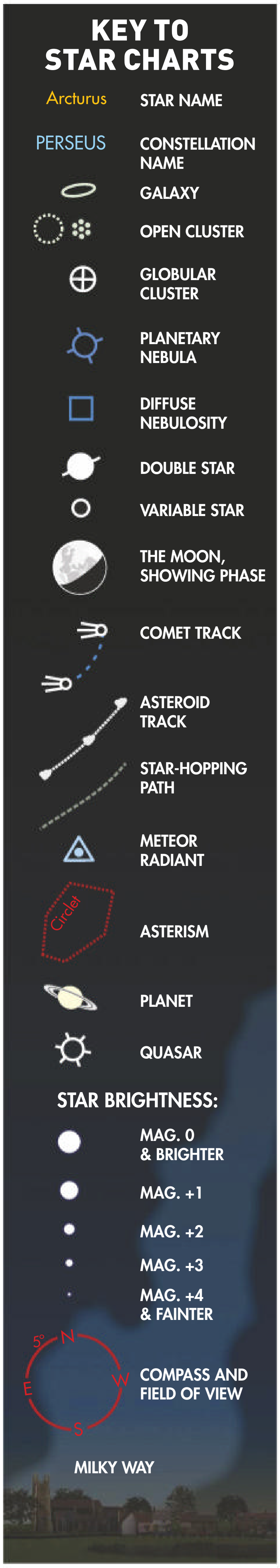



CHART: PETE LAWRENCE

## When to use this chart

**1 August at 01:00 BST**
**15 August at 00:00 BST**
**31 August at 23:00 BST**

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

## How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.


## Sunrise/sunset in August*

| Date | Sunrise | Sunset |
|---|---|---|
| 1 Aug 2021 | 05:26 BST | 21:06 BST |
| 11 Aug 2021 | 05:43 BST | 20:46 BST |
| 21 Aug 2021 | 06:00 BST | 20:25 BST |
| 31 Aug 2021 | 06:18 BST | 20:02 BST |

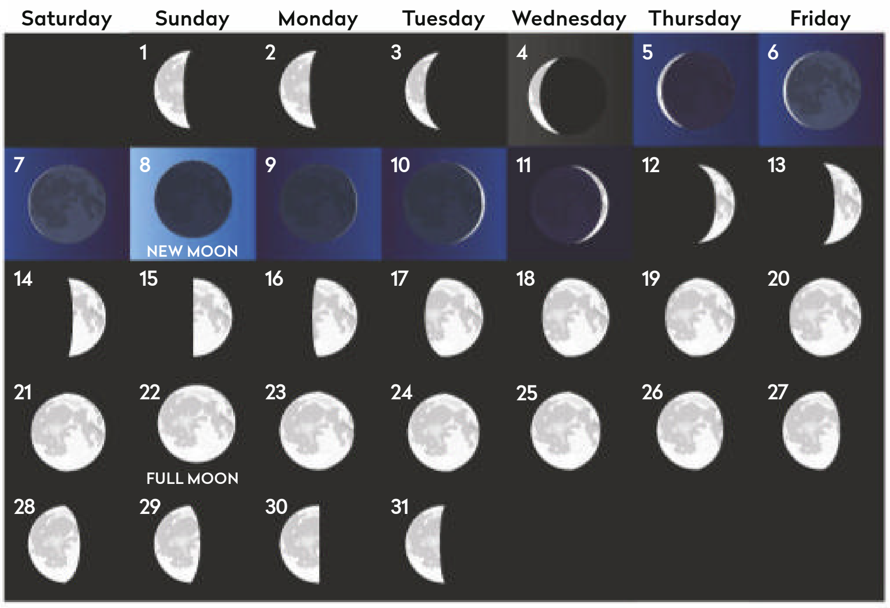
## Moonrise in August*

**Moonrise times**

| | |
|---|---|
| 1 Aug 2021, 00:01 BST | 17 Aug 2021, 17:22 BST |
| 5 Aug 2021, 01:44 BST | 21 Aug 2021, 20:40 BST |
| 9 Aug 2021, 06:10 BST | 25 Aug 2021, 21:41 BST |
| 13 Aug 2021, 11:39 BST | 29 Aug 2021, 22:39 BST |

*Times correct for the centre of the UK

## Lunar phases in August





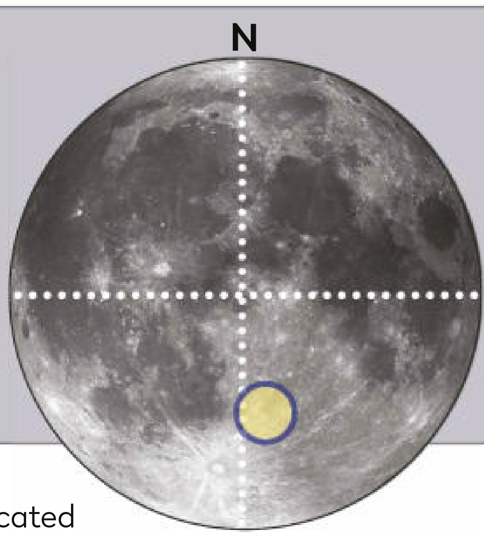
**MORE ONLINE**

**Paul and Pete's night-sky highlights**

**Southern Hemisphere sky guide**

## Delaunay

**Type:** Crater
**Size:** 46km
**Longitude/Latitude:** 2.6˚E, 22.3˚S
**Age:** Older than 3.9 billion years
**Best time to see:** First quarter (15 August) or six days after full Moon (29 & 30 August)
**Minimum equipment:** 50mm telescope




**Delaunay** is a misshapen 46km crater located near the Moon's prime meridian. It's located south of the Moon's equator in a complex highland region to the east of Mare Humorum. There are two guides to its location which will be visible in the same part of the lunar phase cycle as Delaunay itself. To the north lies the large 136km walled-plain of Albategnius, while to the south is the smaller but sharper, 70km crater **Werner**. Delaunay lies roughly one-quarter of the way north of Werner along an imaginary line joining the centres of Albategnius and Werner.

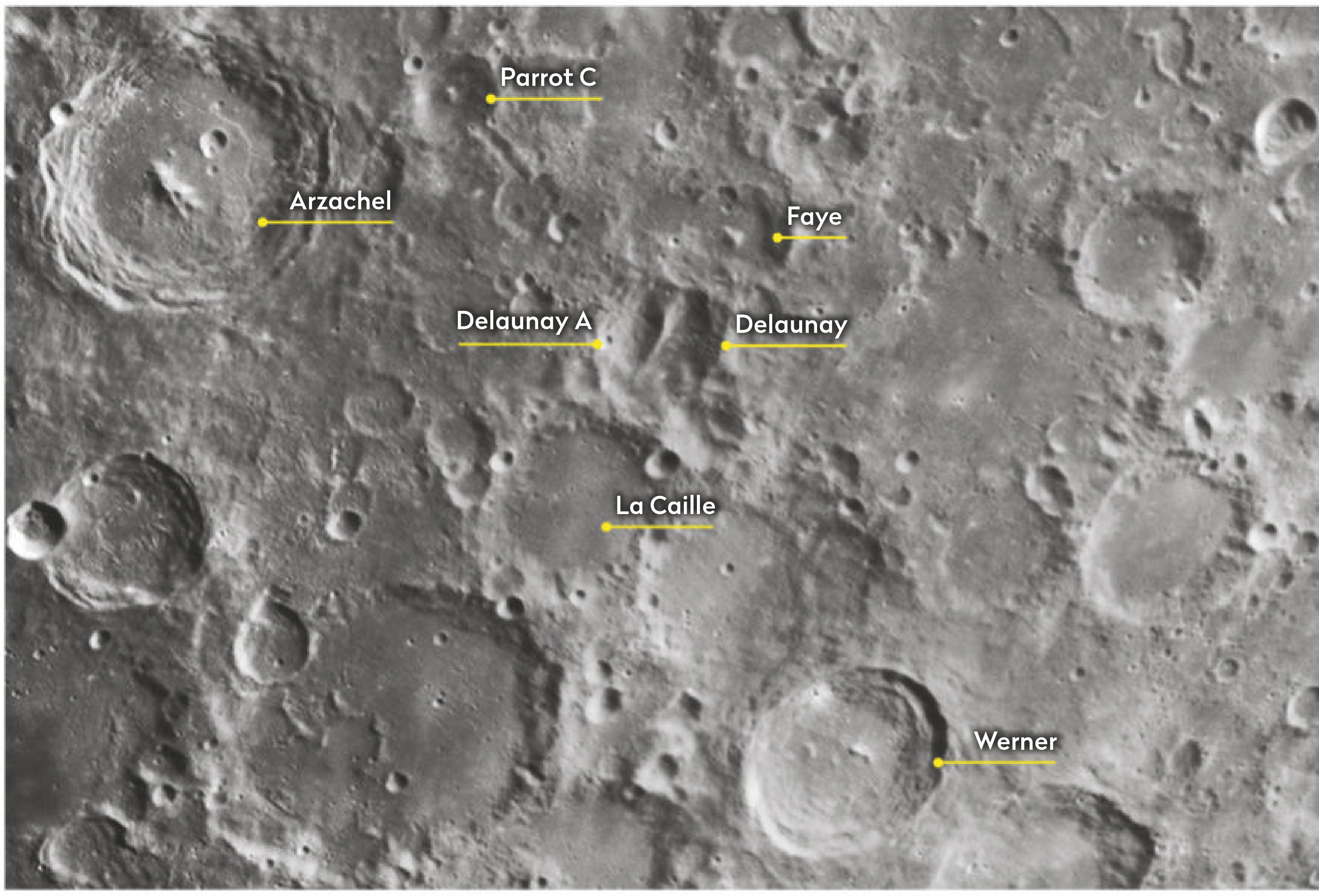
Delaunay is unusual in that on a first visit it doesn't really look like a regular crater. Its sides are irregular as a consequence of its great age and it nestles in an uncomfortable manner between 36km **Faye** to the northeast and 68km **La Caille** to the southwest. Indeed, it looks like there has been a border conflict to the northeast between Delaunay and Faye, the co-joined rim sections of both craters appear to have been pushed into a more linear shape than the usual arcs you would expect.

As Delaunay stretches towards the southwest, it elongates in a way that creates a strawberry or heart-shaped outline. There is a very distinctive ridge that runs down the centre of the crater. This is best defined to the north, thinning out into a narrow divider as it heads southwest. The ridge helps to create confusion here, as it looks on first glance as if Delaunay is actually two smaller craters with rims squashed together at the ridge.

The inner surface of Delaunay is complex and multi-faceted. The wider, northern portion of the ridge opens out into a small plateau shaped like an equatorial triangle with sides approximately 10km in length. The region that could loosely be claimed to be the eastern rim appears as a similar triangular plateau of slightly larger dimensions. A number of rounded, elevated features can be seen towards the south of the crater, their raised surfaces eventually merging with the thinning central ridge.

On Delaunay's western rim is the 6km satellite crater, **Delaunay A**, a reasonable test for a 100mm telescope. The other small craters that appear scattered around Delaunay are officially designated satellites of Faye and La Caille. Located 180km to the northwest of Delaunay's centre is the impressive form of 98km **Arzachel**, the southernmost crater in the distinctive north–south run of three major craters, along with 154km Ptolemaeus to the north and 118km Alphonsus in the middle. The region to the east of this trio and north of Delaunay is peppered with parallel grooves. These are likely to have been formed at the time of the impact which created the massive 1,250km Mare Imbrium basin located further to the northwest. A good example of one of these grooves can be seen leaving the southeast rim of 31km **Parrot C**, which is located to the northwest of Delaunay. It's an interesting exercise to see how far you can follow this groove as it heads north towards the eastern rim of Alphonsus.

*As Delaunay stretches towards the southwest, it creates a strawberry or heart-shaped outline*




▼ **Delaunay's unusual shape and parallel grooves are likely to have been caused by the same impact that created the Moon's Mare Imbrium basin**

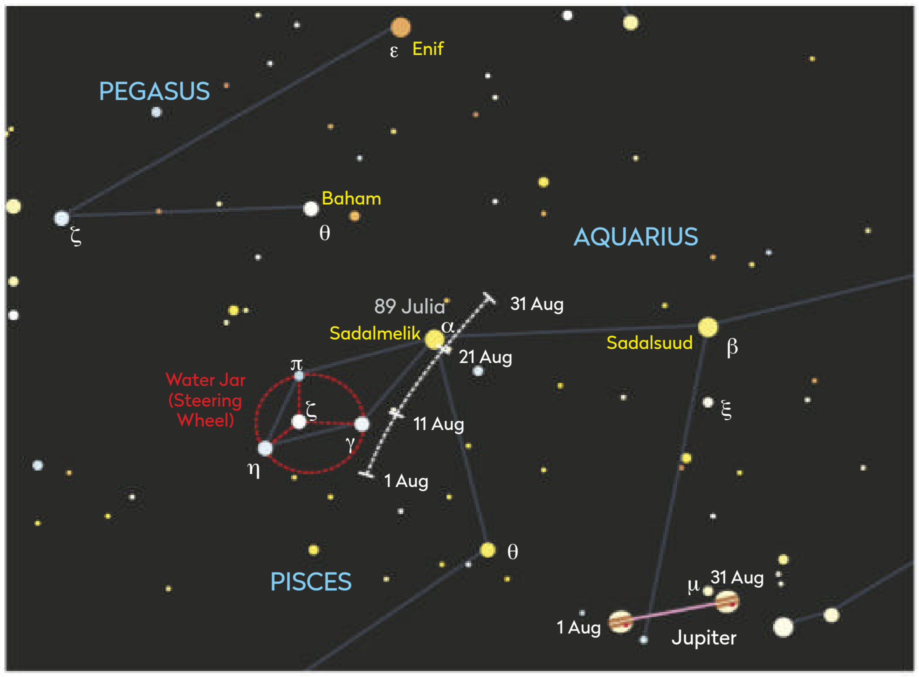
PETE LAWRENCE X 3

# COMETS AND ASTEROIDS

## View Asteroid 89 Julia as it reaches opposition in Aquarius, the Water Bearer

Minor planet 89 Julia reaches opposition in Aquarius this month, shining at mag. +9.0 near the Water Jar asterism. The Water Jar, or 'Steering Wheel', is formed of four similar brightness stars in the northern regions of Aquarius. It sits south of the triangle that forms the upside-down head of Pegasus and to the west of the faint Circlet asterism in Pisces. Its four stars are mag. +4.3 Zeta (ζ) Aquarii in the centre, mag. +4.4 to +4.7 variable star Pi (π) Aquarii to the north, mag. +4.0 Eta (η) Aquarii to the east and mag. +3.8 Gamma (γ) Aquarii to the west. The asterism lies 5° east of mag. +2.9 Sadalmelik (Alpha (α) Aquarii) and is quite easy to locate.

At the start of August, 89 Julia is located a little over 1.5° south-southeast of Gamma Aquarii and from here tracks west-northwest to pass one-third of a degree south of Sadalmelik on the night of 21/22 August. On 1 August, Julia shines at mag. +9.5, as mentioned above, brightening to mag. +9.0 on the 25th, when it reaches opposition. It then retains this brightness through to the month's end. Consequently, 89 Julia may be observed with a small telescope throughout August. To confirm an observation, image or sketch the region in which you think the asteroid is lurking over the course of several nights. If you're looking in the correct place, the asteroid's star-like dot will appear to move.




▲ **Track asteroid 89 Julia as it passes close to the Water Jar asterism**

89 Julia orbits the Sun in the main asteroid belt region between Mars and Jupiter. It's a large object, being around 150km across. It's a stony or siliceous asteroid (S-type) discovered in 1866 by the French astronomer Édouard Stephan and it's named after Saint Julia of Corsica.

# STAR OF THE MONTH

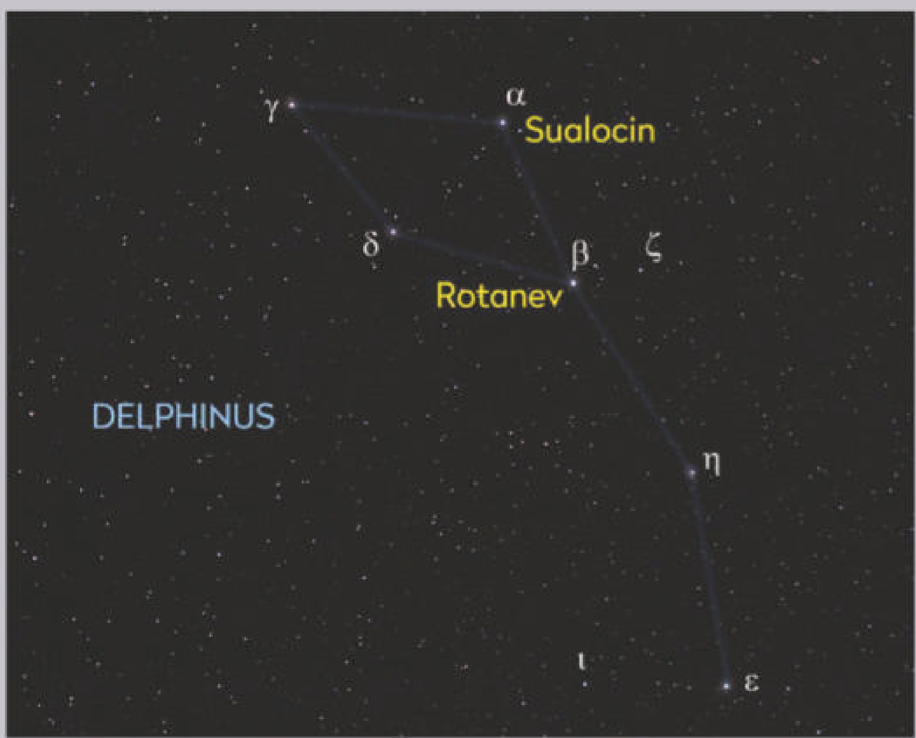
## Sualocin, marking the Dolphin's outline

Delphinus is a small but very identified constellation representing the head and neck of a bottlenose dolphin. It lies 12° to the east and slightly north of the bright star Altair (Alpha (α) Aquilae), which marks the bottom vertex of the giant Summer Triangle asterism, which is well placed at this time of year. Delphinus resembles a diamond shape with a tail. The two stars on the western side of the diamond, Alpha (α) and Beta (β) Delphini, have the unusual names of Rotanev and Sualocin, more of which to follow.

Sualocin is a binary star with five additional companions which are most-likely just line-of-sight acquaintances. The binary star consists of Alpha Delphini Aa (Sualocin) and Alpha Delphini Ab. The pair appear close with a separation of just 0.2 arcseconds and take 17 years to complete one mutual orbit around each other. The secondary is about one-tenth as bright as the primary and of spectral class A. Aa has a spectral type B9IV, indicating it's a hot white subgiant. Despite its alpha designation, at mag. +3.8 Sualocin is the second brightest star in Delphinus after mag. +3.6 Rotanev.

Sualocin (Aa) lies at a distance of 254 lightyears and has a mass 2.8 times as great as our Sun. It's temperature is estimated at 11,340°C.

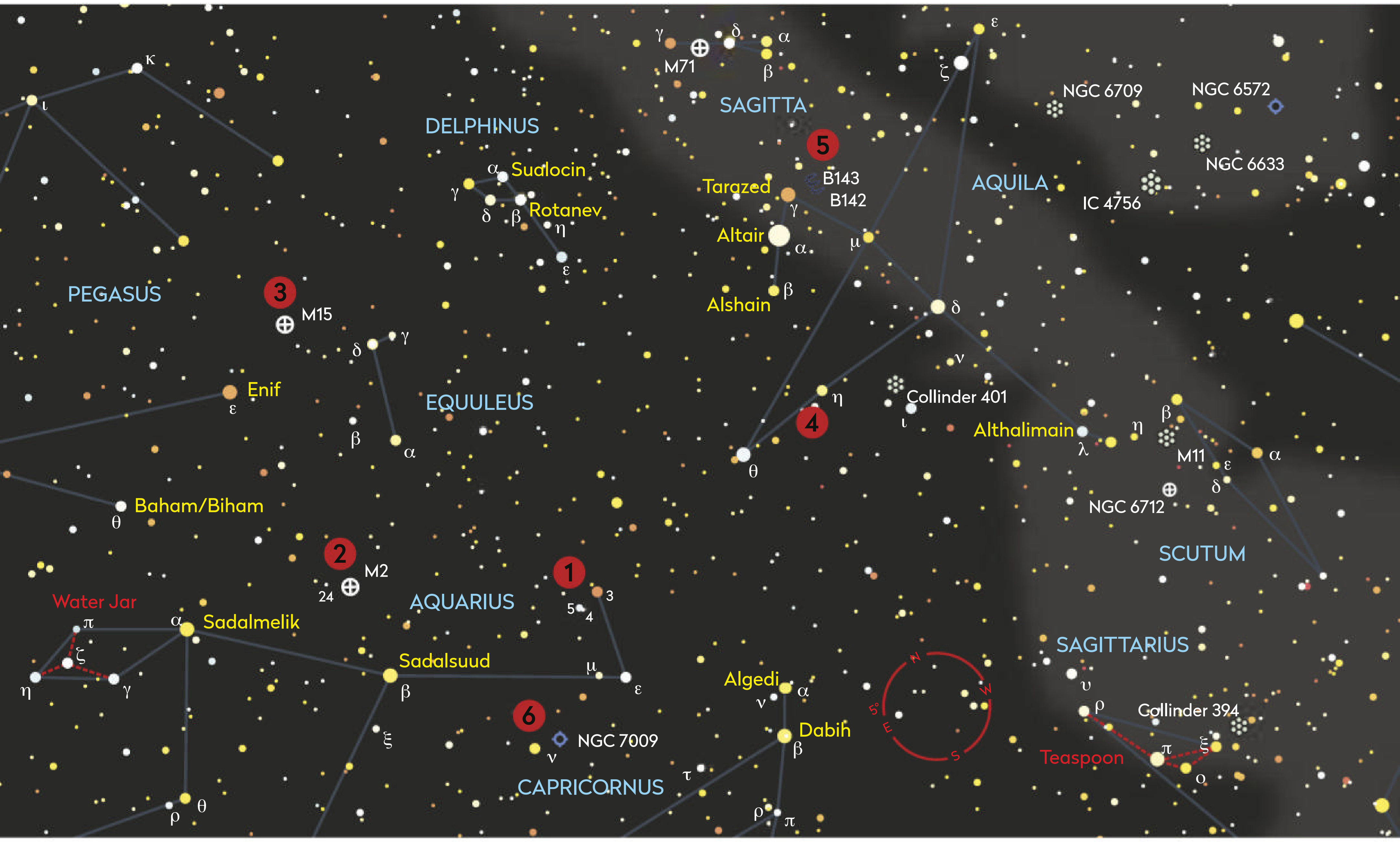
▼ **The star names Sualocin and Rotanev have a puzzling backstory**




The names Sualocin and Rotanev first appeared in the Palmero star catalogue of 1814. Astronomer Thomas Webb worked out that they represent the name of an assistant to the Palmero Observatory's astronomer, Guiseppe Piazzi. The latinised name of the assistant was Nicolaus Venator; reverse the letters and you get the star names.

# BINOCULAR TOUR With Steve Tonkin

This month's wide-field wonders include Barnard's E and two globular clusters




### 1. 3, 4 and 5 Aquarii

10x50 4 and 5 Aquarii comprise a very easy double star, at mag. +5.5 and mag. +6.4 respectively, separated by 13 arcminutes. This is a line-of-sight pairing, not a true binary star. A degree or so to the northwest you will see a brighter orange star. This is the slightly variable (mag. +4.4 to +4.5) 3 Aquarii. If you enjoy looking at coloured stars, scan the region 5° northwest of 3 Aquarii. ☐ **SEEN IT**

### 2. M2

10x50 The globular cluster M2 forms a right-angled triangle with Sadalsuud (Beta (β) Aquarii) to the south and Sadalmelik (Alpha (α) Aquarii) to the east. It stands out, even in small binoculars, in an otherwise sparse region of sky, looking exactly as Charles Messier described it: "a nebula without stars". Try averted vision by directing your gaze to 24 Aquarii, 1° east of the cluster, and you might notice that it appears slightly oval. ☐ **SEEN IT**

### 3. M15

10x50 Our second globular cluster, M15, is another easy target. Find it by extending a line from Biham (Theta (θ) Pegasi) to Enif (Epsilon (ε) Pegasi) another 4° northwest. It appears rounder and brighter than M2, but do not expect to see it even half as wide (18 arcminutes) as planetarium programs suggest. Most of its stars are densely concentrated into the core so only the central third of it is visible in 50mm binoculars. ☐ **SEEN IT**

### 4. Eta Aquilae

10x50 In 1784, the York-based astronomer Edward Piggott announced the discovery of a star that varied in brightness: Eta (η) Aquilae. This is one of the brightest Cepheid variables (mag. +3.5 to +4.4, with a period of 7.18 days), and it was found a month before his collaborator, John Goodricke, discovered the variability of Delta (δ) Cephei, the star that gives that class of variable star its name. ☐ **SEEN IT**

### 5. Barnard's E

10x50 This is one of the easiest dark nebulae. You'll find it 1° west of Tarazed (Gamma (γ) Aquilae). It's actually a pair of nebulae, B142 and B143, which stand out against the star-rich Milky Way background, making them easy to find and identify. Choose a dark transparent night if this is your first attempt at dark nebulae, and the obscuring gas and dust will appear either as an uppercase 'E' or an underlined 'C'. ☐ **SEEN IT**

### 6. The Saturn Nebula, NGC 7009

15x70 You'll need dark, transparent skies for this nebula, but it is easy to locate: identify Nu (ν) Aquarii and it is 1.3° due west. NGC 7009 will look like a defocused star but, even if you use a UHC (Ultra High Contrast) or O-III (Oxygen) filter, your binoculars won't show the elongation that gives it its name. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

# THE SKY GUIDE CHALLENGE

## Can you spot and record a meteor train, which lingers after its trail has faded

◄ **Capture a meteor train on a camera and you'll record it for longer than you can visually. To do so, keep your exposures short at 20-30 seconds**

August is great for meteors. Given clear skies, a favourable Perseid maximum will provide many trails with other active showers adding to the mix too. This month's challenge is to try and record a phenomenon often seen following a bright meteor, a glowing entity known as a meteor train.

A meteor trail represents the death throes of a typically small rock or meteoroid ablating in our atmosphere. Often incorrectly described as burning, the actual process is more complex. As the meteoroid enters our atmosphere it compresses air ahead of it which generates heat. The heat is sufficient to vaporise the forward face of the meteoroid. Liberated atoms interact with atmospheric atoms raising their energy state. A short time later, the excited atoms return to their ground state, releasing the energy given to them as visible light. This is what forms the trail, a line of light typically a metre or so in width and several tens of kilometres in length.

A larger particle, say the size of a grape or perhaps a golf ball, produces a brighter trail. It may also cause enough ionisation for the column of glowing atoms to persist for some time after the trail has faded, and this is known as a meteor train.

The longevity of a train, typically just a few seconds, is related to the brightness of the trail, brighter trails producing more persistent trains. An important observation is to estimate the brightness of a meteor trail and record the length of the resultant train in seconds. If you have enough data, this can be used to predict the persistence length of a train for a given brightness of trail. Trail brightness can be recorded visually, but photographically it's necessary to tie up a visual estimate with a known photographic trail. In this way it is possible to roughly calibrate your camera so you can estimate visual trail brightness from a photographed trail.

The longer a train is visible, the greater the chances it will distort due to high-altitude atmospheric winds. For meteor imaging, keeping exposures reasonably short, say to 20–30 seconds, may allow you to record and animate these distortions over time. It's also worth noting that this length of exposure will allow you to record a train for longer than would be the case visually. Photographic trains have longer persistence due to greater camera sensitivity.

If you manage to photograph a bright trail, flick from the trail image through the few that follow it to see whether a train has recorded too. Animating these images will allow the movement of the ionised gases in the train to become quite obvious.

# DEEP-SKY TOUR

From the Teapot asterism's vicinity, we take in celestial gems and hop outside the Milky Way

**1 M22**

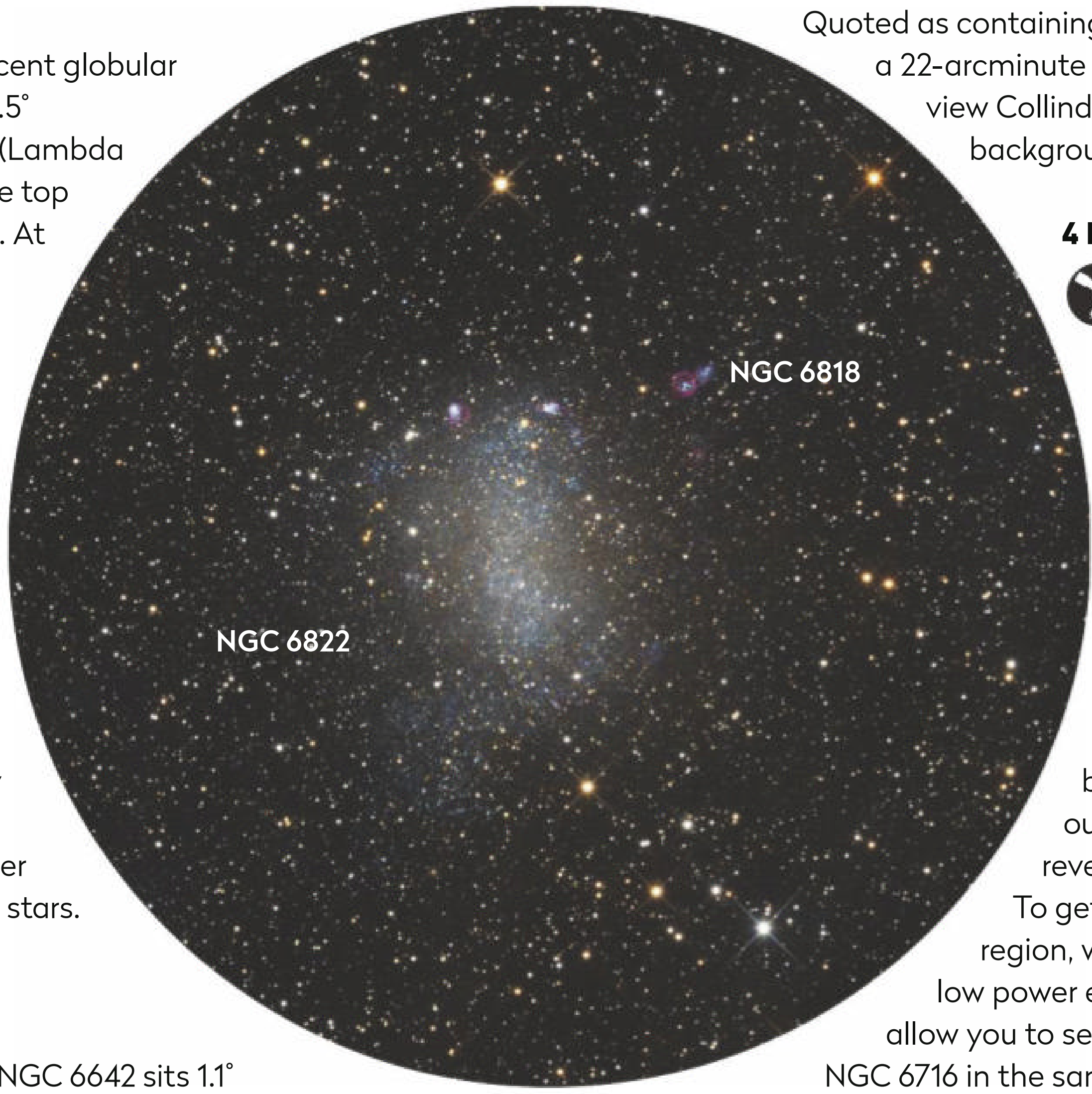
M22 is a magnificent globular cluster located 2.5° northeast of Kaus Borealis (Lambda (λ) Sagittarii), the star at the top of the Teapot asterism's lid. At mag. +5.1 it is visible to the naked eye, but a telescope brings out its beauty. From the UK, M22 is compromised due to its low altitude. A 150mm scope at around 200x magnification reveals many resolved stars across the globular's core. The whole object is around 20 arcminutes across and appears slightly elongated in a southwest–northeast orientation. Larger instruments resolve further stars. ☐ **SEEN IT**

**2 NGC 6642**

Globular cluster NGC 6642 sits 1.1° west-northwest of M22's centre. Locating NGC 6642 isn't the problem, it's getting detail that proves tricky. Shining at an integrated magnitude of +7.6, NGC 6642 is tiny. A small scope shows it as a 1 arcminute glow. The glow appears larger and brighter through a 250mm instrument, but without obvious resolution. The best you can expect using averted vision under dark-sky conditions is subtle mottling. Don't be fooled by several field stars giving the false impression you're beginning to resolve NGC 6642. A 300mm scope increases the glow's size to around 1.5 arcminutes, perhaps hinting at a bit of resolution. ☐ **SEEN IT**

**3 Collinder 394**

This part of the sky is rich with 'local' deep-sky objects found within our own Milky Way. In the direction of Sagittarius, you're looking towards the Galaxy's core and the number of faint background stars is high. Locate Collinder 394 by using two stars in the Teaspoon asterism. Extend the line from Omicron (ο) Sagittarii to Xi-2 ($\xi^2$) Sagittarii by three-quarters of their separation again to arrive in the correct area. A low power is recommended. Quoted as containing as many as 50 stars in a 22-arcminute area, it's interesting to view Collinder 394 against its rich background. ☐ **SEEN IT**




▲ **The final stops on August's tour are Barnard's Galaxy, NGC 6822, and its tiny neighbour, the Little Gem, NGC 6818**

MARKUS BLAUENSTEINER/CEDIC TEAM/CCDGUIDE.COM, CHART BY PETE LAWRENCE

**4 NGC 6716**

Our next target sits 56 arcminutes northeast of Collinder 394. Open cluster NGC 6716 has an integrated magnitude of +7.5 and appears well-defined thanks to having the compact size of 10x8 arcminutes. A series of brighter stars gives the cluster a distinctive rectangular, bordering on elliptical, outline. A 250mm instrument reveals around 30 cluster stars. To get the best out of this region, we'd recommend using a low power eyepiece and this should allow you to see both Collinder 394 and NGC 6716 in the same field of view. ☐ **SEEN IT**

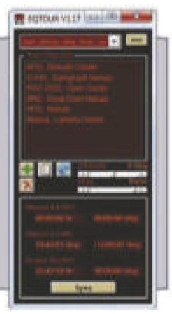
**5 NGC 6822**

We hop outside the Milky Way for our next target, NGC 6822, also known as Barnard's Galaxy. This is a barred irregular galaxy 1.6 million lightyears from our location. It's sited east of the Teaspoon asterism and easily found by extending the line from Xi-2 Sagittarii through Rho-1 ($\rho^1$) Sagittarii for 6.3°, or roughly the same distance again. NGC 6822 is a tricky spot due to it shining with an integrated magnitude of +9.3 and having an apparent size of 16x14 arcminutes. This gives the galaxy a low surface brightness. A small scope with a low power will show it. The galaxy should appear as a gently elevated glow compared to the background sky, with a hint of a subtle central condensation. ☐ **SEEN IT**

**6 NGC 6818**

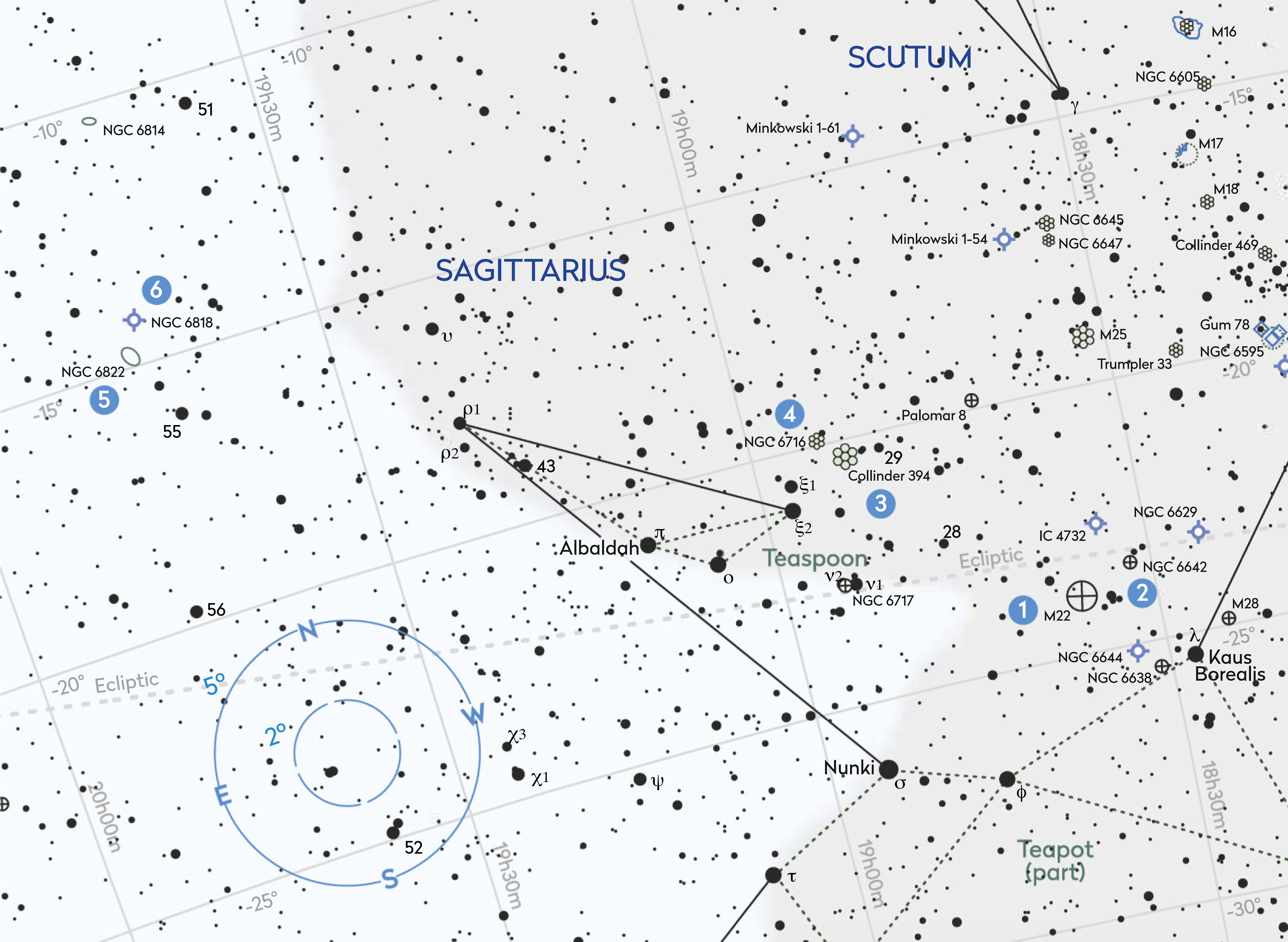
Our final target is planetary nebula NGC 6818, situated 0.7° to the north-northwest of the centre of NGC 6822. Known as the Little Gem, this nebula shines at mag. +9.3 and has apparent dimensions of 22x15 arcseconds. A small instrument will show it as a bright blue-hued disc. A 250mm scope reveals the nebula to be sharply defined around its outer edge and hints at a darkening in its core regions. NGC 6818's central star shines at 15th magnitude and requires an aperture over 380mm to see visually. Although a local Milky Way object, this is a relative term as the nebula is around 6,000 lightyears away. ☐ **SEEN IT**

**This Deep-Sky Tour has been automated**
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.



More **ONLINE**

**Print out this chart and take an automated Go-To tour. See page 5 for instructions.**


SCUTUM
SAGITTARIUS
M16
NGC 6605
γ
M17
M18
NGC 6645
NGC 6647
Collinder 469
Minkowski 1-61
Minkowski 1-54
M25
Gum 78
NGC 6595
Trumpler 33
Palomar 8
NGC 6716
29
Collinder 394
ξ1
ξ2
3
4
28
IC 4732
NGC 6629
NGC 6642
Ecliptic
Teaspoon
ν2
ν1
NGC 6717
M22
1
2
M28
λ
Kaus Borealis
NGC 6644
NGC 6638
Albaldah
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ρ1
ρ2
43
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51
NGC 6814
6
NGC 6818
NGC 6822
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56
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W
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5°
2°
-20° Ecliptic
χ3
χ1
ψ
52
Nunki
σ
φ
τ
Teapot (part)
19h30m
19h00m
18h30m
20h00m
-10°
-15°
-20°
-25°
-30°

# AT A GLANCE

How the Sky Guide events will appear in August

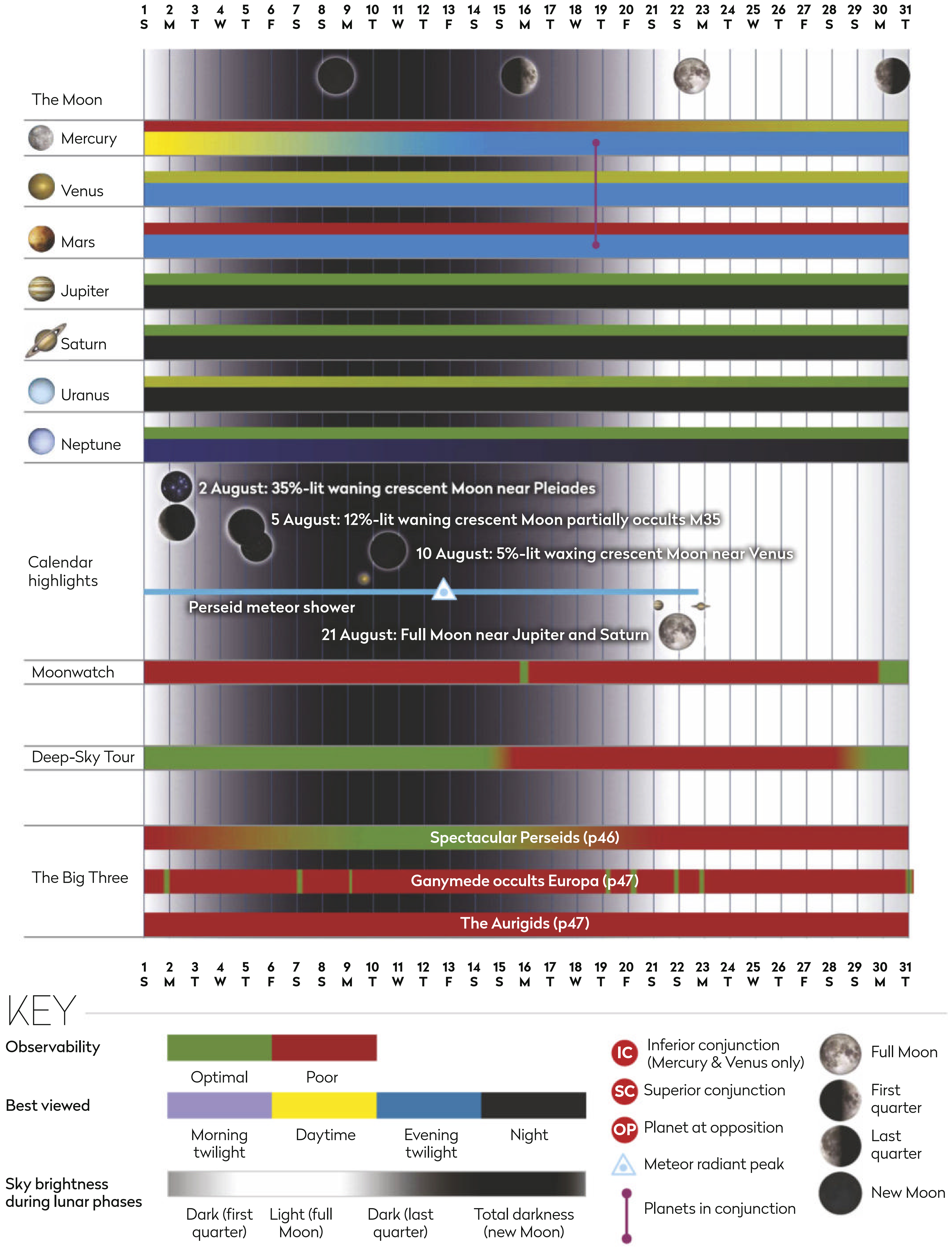



CHART BY PETE LAWRENCE

# Juno's Jupiter journey CONTINUES

## With its mission extended by four years, the Juno spacecraft still has a lot to learn about the gas giant, as **Ezzy Pearson** discovers

For the last five years the undisputed king of the planets has been watched over by the Juno spacecraft. During its swooping passes, the NASA orbiter has imaged the upper cloud deck and peered into the planet's depths, mapping out the gas giant's magnetic and gravitational structure to create a three-dimensional picture of the Solar System's largest planet.

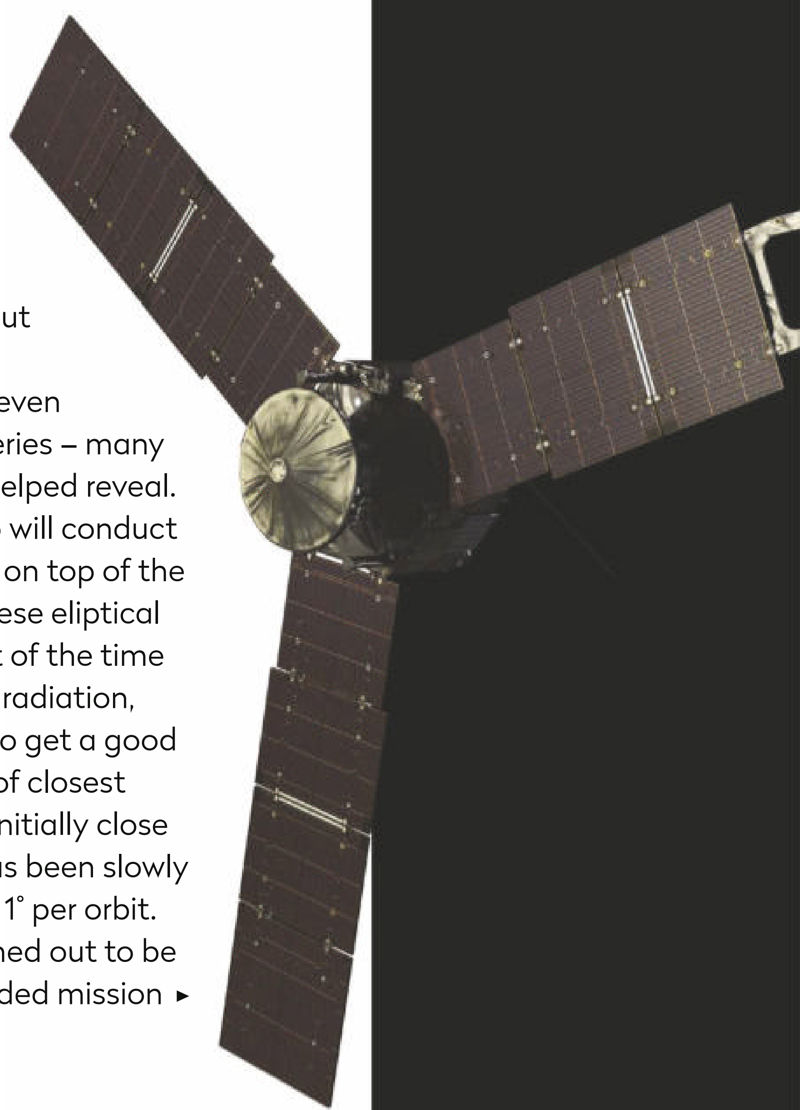
The mission was originally intended to meet its fiery end this August, crashing into Jupiter's atmosphere. But in January Juno was granted a reprieve and the mission has been extended to September 2025.

Juno's original end date was predicted based on the number of orbits required to map out Jupiter before the intense radiation created by the planet's massive magnetic field ravaged the probe's electronics. To protect Juno as long as possible, the most important components were locked inside a vault made of 1cm-thick titanium, designed to stop all but the most energetic radiation.

Scott Bolton from the Southwest Research Institute, Juno's Principal Investigator, is upbeat about how well the craft's protection has performed. "So far, we have not seen any signs of significant radiation related degradation that's important to us," he says. "We built an armoured tank and it turned out our shielding is holding up."

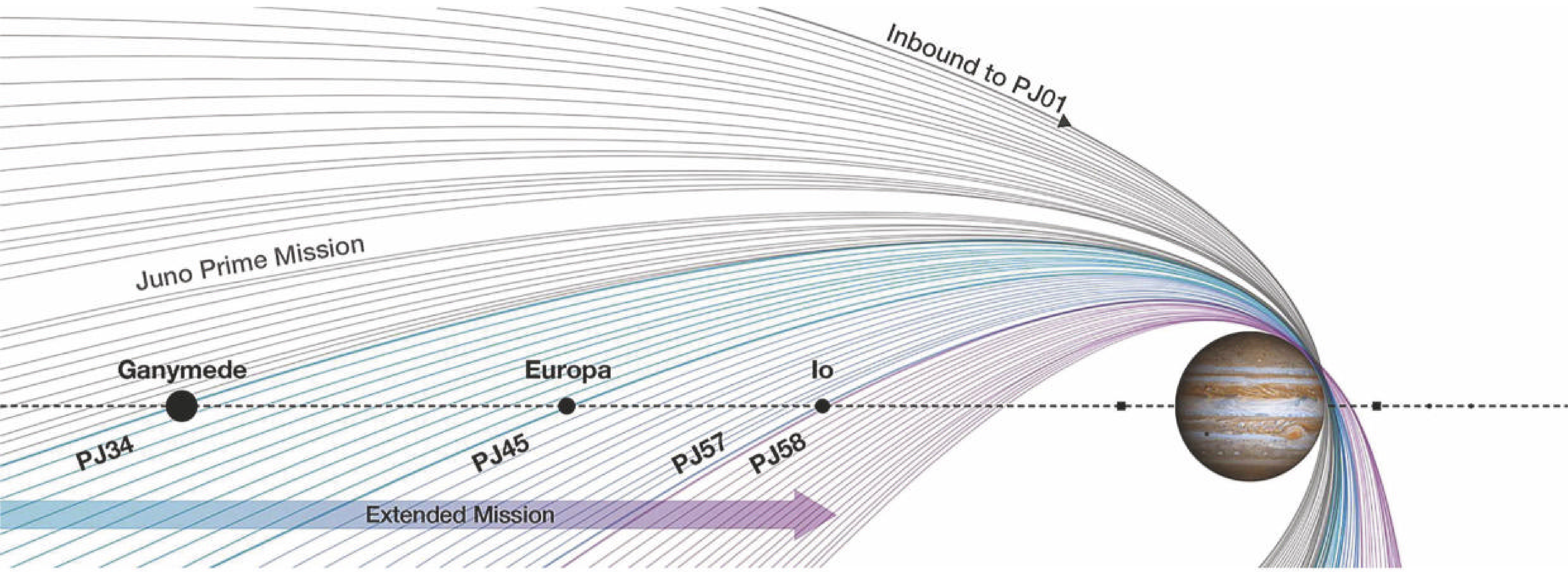
The mission can now delve even deeper into the planet's mysteries – many of which the probe itself has helped reveal. Over the next four years, Juno will conduct 42 additional orbits of Jupiter, on top of the 34 from the prime mission. These eliptical orbits swing out wide for most of the time to avoid the worst of Jupiter's radiation, before quickly diving in close to get a good look at the planet. This point of closest approach (the 'perijove'), was initially close to the planet's equator, but has been slowly creeping northwards at about 1° per orbit.

The northward drift has turned out to be hugely beneficial to the extended mission ▸



NASA/JPL-CALTECH/SWRI/MSSS/ALIABBASIPOV, NASA/JPL

During its extended mission, Juno (inset) will give scientists an opportunity to explore Jupiter's stormy features in more detail than ever before




▸ though, as it will now be able to take a closer look at several interesting features that the prime mission revealed. As Juno passes over the poles, rather than circling the equator, planetary scientists attained their first ever close-up of these regions, revealing they were dominated by huge, swirling storms.

"We'll be able to study the storms in the north in ways never before possible," says Bolton. "We really don't understand how they form, why they're stable or what happens over time. We'll be able to look deep into the atmosphere, underneath the giant vortices and see how they compare to the large vortex storms at lower latitudes, like the Great Red Spot."

During the extended mission, Juno will get close enough to use its Microwave Radiometer, which can pierce up to 400km down through the clouds to look at both the storms' root structures and the distribution of water and ammonia within them – both important chemicals for understanding how the planet's atmosphere behaves.

"We know that Jupiter's deep atmosphere changes, but how does that change happen as you go further north? What happens when the stripes that we call the zones and belts – where the winds go back and forth – start to change?" says Bolton.

## Creating a storm map

One of the areas they'll be paying particular attention to is where these stripes transition into the giant polar cyclones. Juno's northward creeping will allow it to create a gravitational map of these storms. It does this by taking careful measurements of its orbit, which can be compared to its predicted path to see where gravity has pulled it off course. If the spacecraft is deflected, then gravity is stronger and that part of the planet is denser than expected, and vice versa.

"The zones and belts go through some kind of transition at northern latitudes, so getting more gravity data closer up will help investigate what happens during that transition," says Bolton.

**▲ The extended Juno mission involves 42 additional orbits, including flybys of Jupiter's moons Ganymede (PJ34), Europa (PJ45) and Io (PJ57 and PJ58) – with 'PJ' referring to 'perijove', the point in each orbit where Juno comes closest to Jupiter**

**▼ Using data from the Juno mission, this illustration depicts high-altitude electrical storms on Jupiter**

Another area Juno will look into is the lightning that jumps between Jupiter's clouds. At lower latitudes Juno observed this lightning occurring at high altitudes, suggesting there must be liquid water clouds far above where they were expected.

"It should all be frozen at the altitude we saw the lightning," says Bolton. "Most theories of lightning, the kind we're seeing, suggest it needs three phases of something – liquid, gas and ice. There must be some sort of liquid at the altitude of the lightning, but it can't be water because that would all be frozen. We came up with the idea that the ice was being melted by ammonia, which would act like antifreeze."

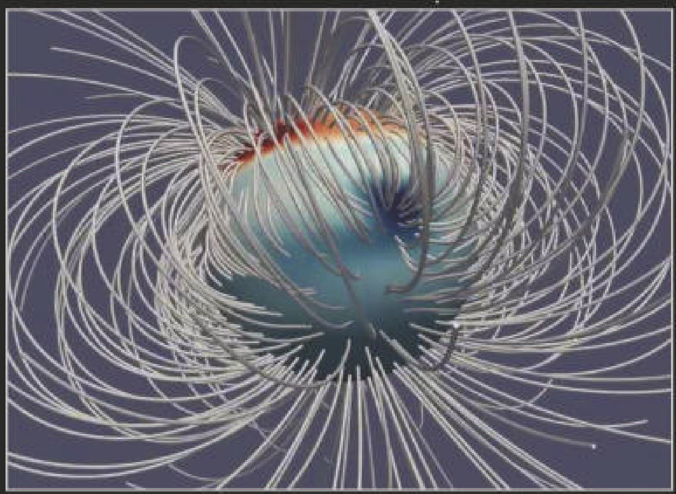
As most of the lightning was at northern latitudes, a closer look at the northern hemisphere will help pin down exactly how much it is happening on Jupiter and where it is.

Juno will also get closer to some of Jupiter's most dramatic features – the aurorae. Like Earth, ▸

# JUNO'S GREATEST HITS

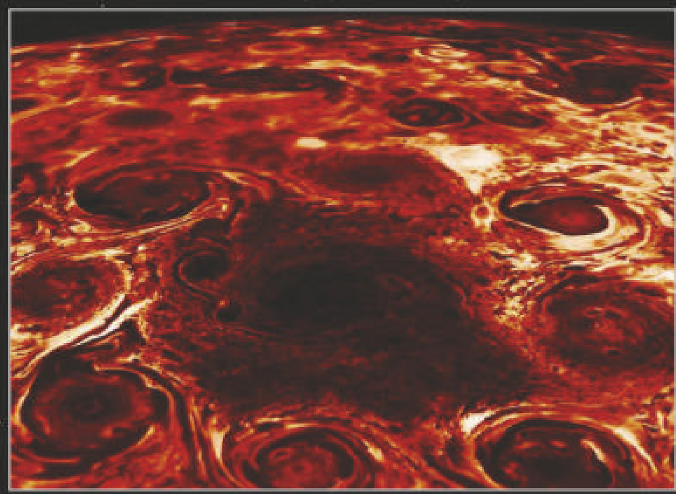
Over the last four years Juno has revolutionised our view of Jupiter

### THE GREAT BLUE SPOT



When the Juno team put together their map of the magnetic field, they discovered a dark spot of highly concentrated magnetism near the equator. Though invisible to the naked eye, the patch appeared blue in their map's colour scheme – hence its name.

### THE STORMS OF THE POLES

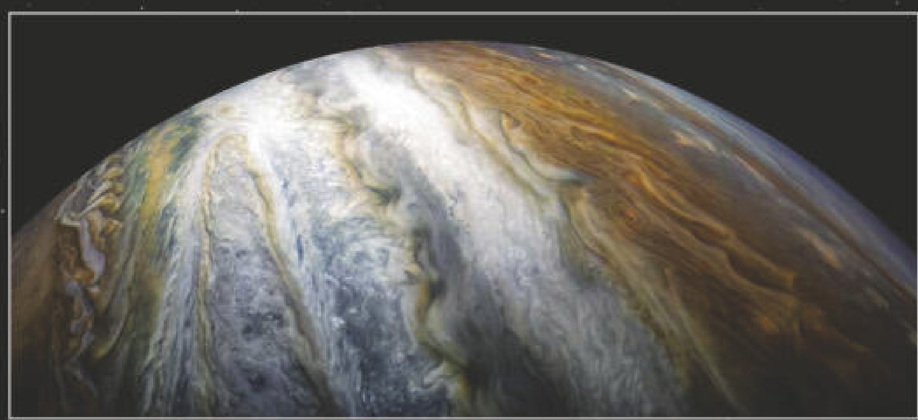


Juno was able to get the first ever look at Jupiter's poles from above, finding they were swarmed by storms. The north pole has a single central storm, surrounded by eight companions, ranging from 4,000km to 7,000km in size, which have remained stable throughout Juno's mission.

### JUPITER HAS WATER

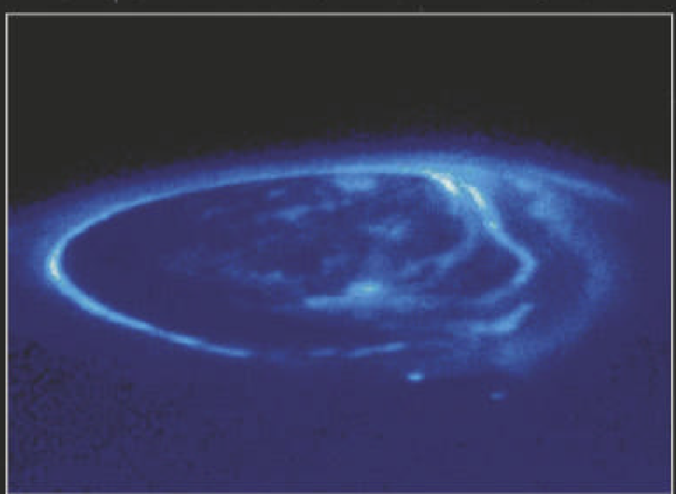

Juno found that Jupiter has three times more water than the Sun, putting to bed a decades-old mystery. In 1995 the Galileo spacecraft's measurements indicated that the planet was far more arid, which suggested that the early Solar System had a lot less water than we see today.

### JUPITER'S BELTS RUN DEEP NEAR THE EQUATOR



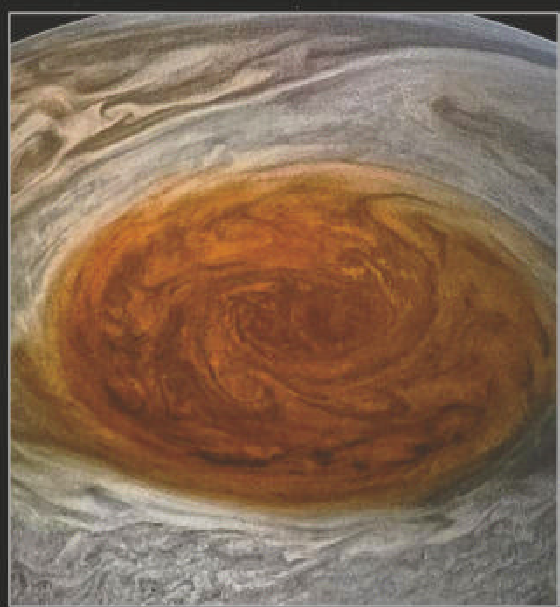
The spacecraft was able to look deep down into the stripes of wind and cloud known as belts and zones. Near the equator the regions go down 3,000km, becoming shallower towards the poles before blending into the polar storms.

### SUPERCHARGED AURORAE



The electrical field around Jupiter's poles, which helps create the aurorae, is around 100 times more charged than Earth's. Juno also discovered a new ring-shaped feature that glows in the ultraviolet and which expands out at around 5km/s.

### THE GREAT RED SPOT – IN 3D



During the first part of its mission, Juno got a good look at the Great Red Spot, a giant maelstrom which has been raging for centuries. The spacecraft measured that the storm reaches down 320km into Jupiter's atmosphere – over 30 times deeper than the deepest point of Earth's oceans.

# Missions after Juno

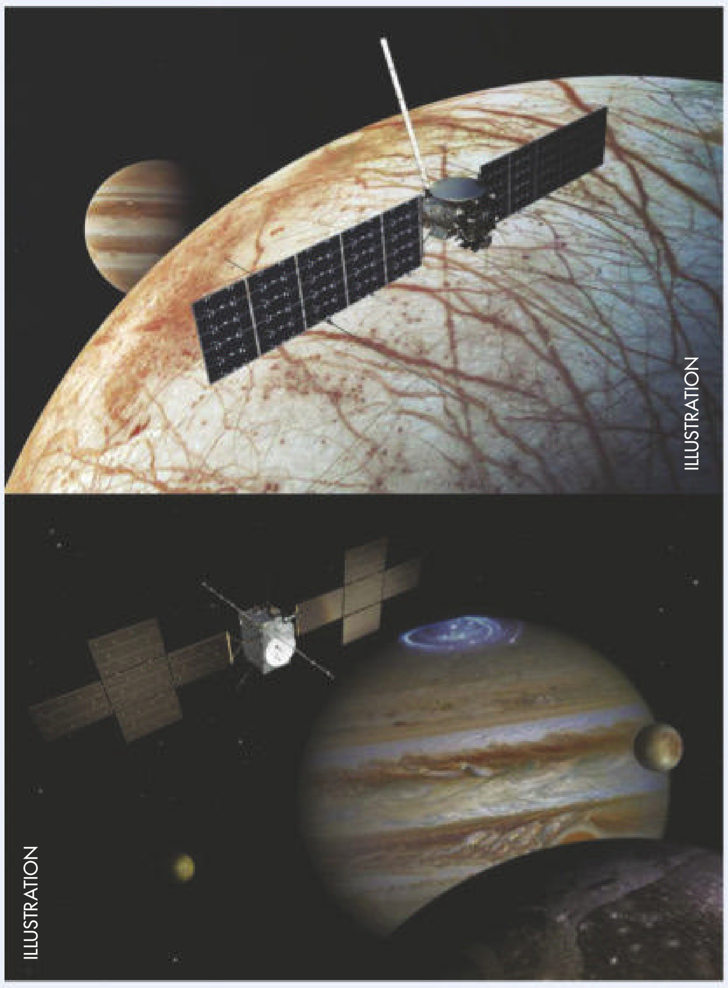
## The next set of Jupiter missions will focus not on the planet, but its moons

The liquid water oceans of Jupiter's icy moons have long held a fascination for planetary scientists, partly for what they can teach us about water in our Solar System and partly because of the tantalising possibility that they might provide havens for life. Now three planned missions will turn their focus on these icy worlds.

First to launch in June 2022 will be the European Space Agency's (ESA's) Jupiter Icy Moons Explorer (JUICE) looking at Jupiter's moons Ganymede, Callisto and Europa. After arriving at the gas giant in 2029, JUICE will spend the first few years orbiting Jupiter, performing flybys of the moons to map out their surfaces visually, while using radar to peer beneath. Finally, in 2032, JUICE will start orbiting Ganymede, the largest moon in the Solar System.

Next up is NASA's Europa Clipper, which is set to launch in October 2024. Previous missions have spotted water plumes erupting from Europa's surface, potentially providing a way to get a close-up of the water on the moon without having to drill through 20km of ice to reach it.

Finally, the Chinese National Space Administration (CNSA) is planning the Gan De probe. The launch is pencilled in for 2029, arriving at Jupiter in 2035, though exactly what it will do there is still being decided. One option is to send it to Callisto, completing the trio of icy moon examinations. Alternately, it could end up visiting the highly volcanic Io and perhaps even sending a lander to the surface. Whatever happens, it looks like Jupiter's moons should prepare for visitors.




► **Top: the Europa Clipper will look for water on its namesake moon Below: Jupiter Icy Moons Explorer (JUICE) will map the surfaces of Ganymede, Callisto and Europa**

► Jupiter's magnetic field captures and accelerates particles, which crash into the atmosphere at high latitudes, creating a glorious light show. But, unlike on Earth, Jupiter's aurorae are largely outside the visible spectrum, shining in the ultraviolet and infrared wavelengths. Juno has already detected some of the accelerated particles, but something else seemed to be missing.

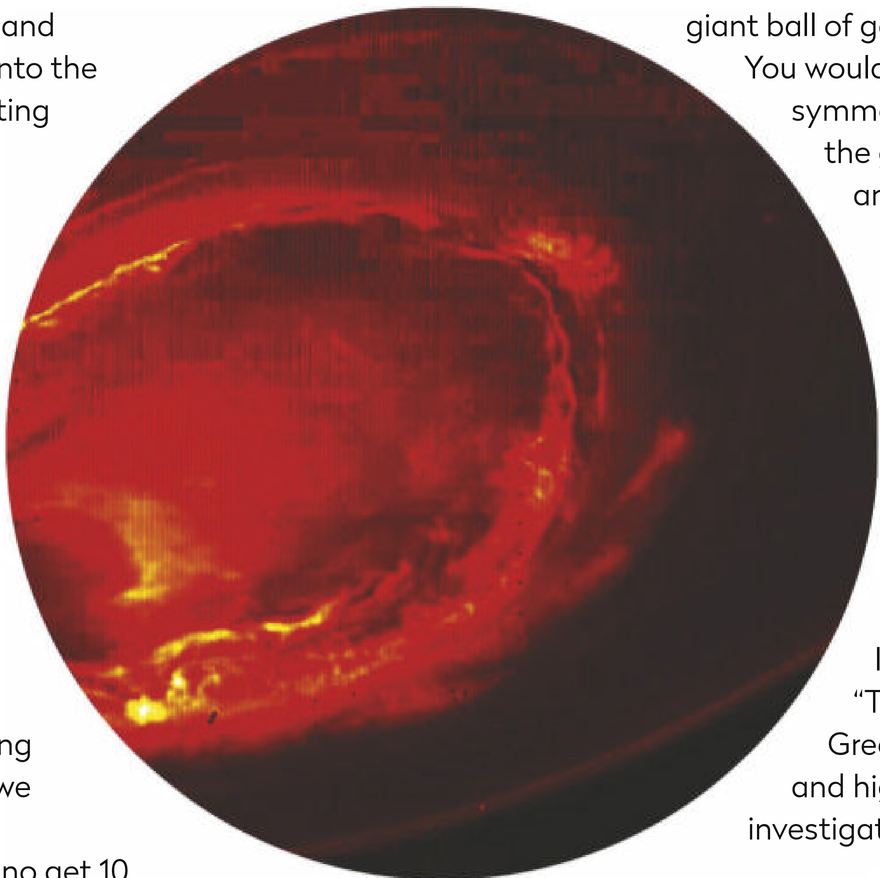
"Even though we were pretty close, we couldn't correlate the [number of] particles that we observed with the aurora that we were seeing," says Bolton. "Some of the particles must be being accelerated closer to Jupiter than we were sampling."

The extended mission will see Juno get 10 times closer to the aurora, allowing it to hunt for these missing particles. It will also be able to look at another piece of the puzzle, the planet's magnetic field.

"The magnetic field up in the north has really got a lot of structure, it has more complexity than the south. We don't fully understand that. All of Jupiter is asymmetric, which is surprising to us, because it's a giant ball of gas, spinning around really fast. You would think it would get more symmetric, but we see asymmetry in the gravity field, the magnetic field and the atmosphere," says Bolton.

One of the magnetic features already seen by Juno further south, at the equator, is a patch of strong magnetism known as the Great Blue Spot, which shows signs that the magnetic field is being pushed around by Jupiter's deep jets or winds.

"When we go to the north, there's a whole bunch of these little features," says Bolton. "They're not quite as big as the Great Blue Spot, but we'll get higher and higher resolution to be able to investigate them."



▲ **Jupiter's southern aurora is barely visible from Earth, because of our planet's position in respect to the gas giant's south pole**

### Lunar flybys

However, not all of Juno's attention will be focused on the planet itself. As the craft's perijove moves northwards, the point at which Juno's orbit crosses the plane of the moons moves inwards, meaning it will make close passes of three of Jupiter's icy moons – one of which has already occurred.

ESA/ATG MEDIALAB, NASA/JPL-CALTECH, NASA/JPL-CALTECH/SWRI/ASI/INAF/JIRAM, NASA/JPL-CALTECH/SWRI/MSSS, NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M. GILL

Juno flew past Ganymede's surface on 7 June 2021, using the manoeuvre to adjust its orbit, reducing the time to loop around Jupiter from 53 days down to 43. Flying just 1,038km from the surface, it was able to take images with a resolution of 600m–900m per pixel. The team are planning to study these images before making any scientific judgements.

The next flyby on 29 September 2022 will see the spacecraft pass within 320km of Europa. During this flyby, Juno will be able to use its Microwave Radiometer to look at the top 10km of ice. This will search for where the ice is thin, or where cracks might appear in the icy crust, allowing water to escape from a subsurface ocean.

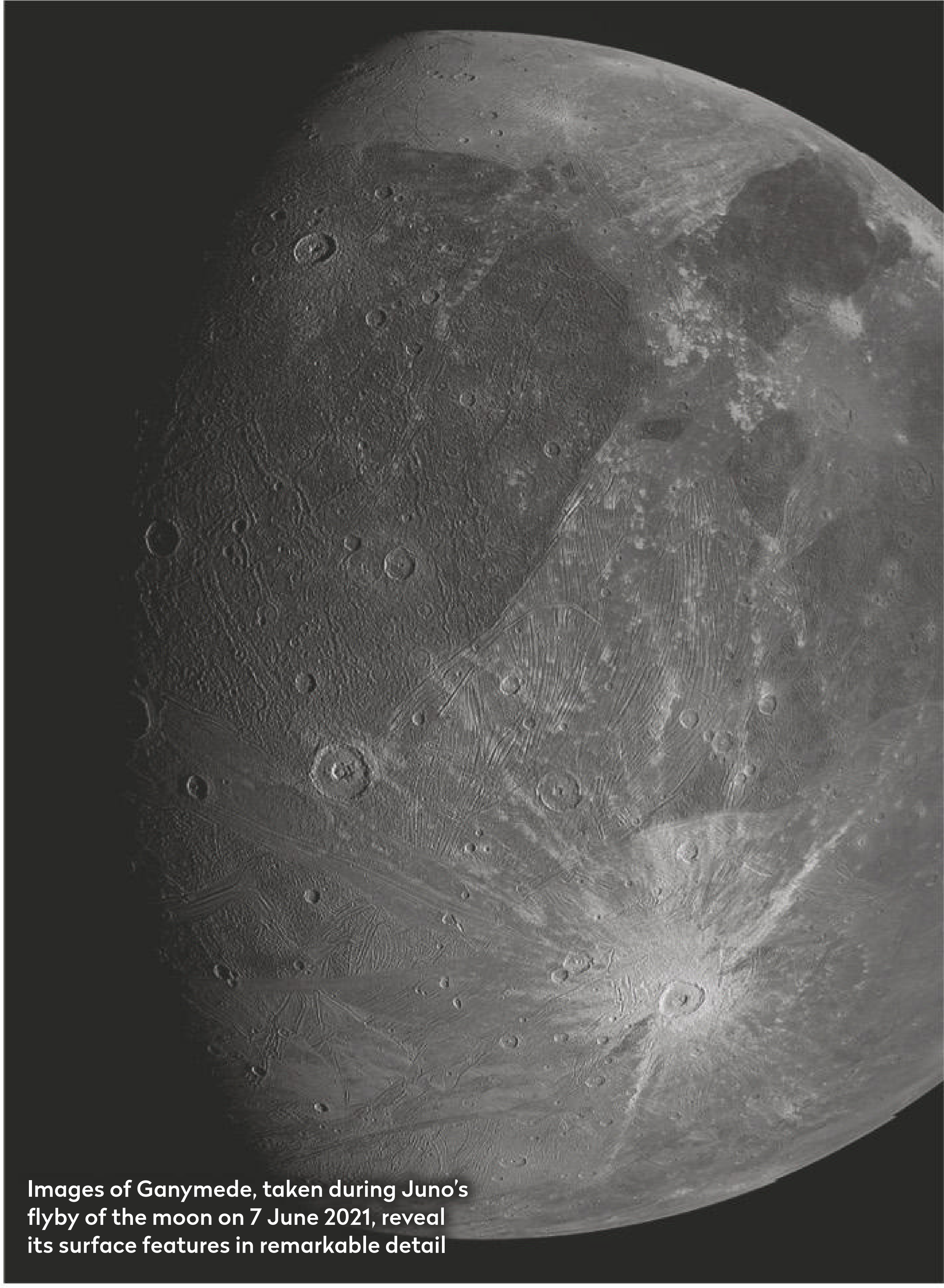
Next, Juno will make two flybys of Io on 30 December 2023 and 3 February 2024, passing either side of the moon 1,500km apart. The moon is known for being the most volcanically active body in the Solar System, leading many to wonder if the surface is covered by a liquid magma ocean. The dual flybys will measure the gravitational layout of the moon, revealing any surface magma.

Finally, the path of the spacecraft will take it far enough in to reach the planet's rings. While you might expect this dust-filled region to be hazardous to the spacecraft, that isn't the case.

"The rings look like they're full of material, but most of it's empty space," says Bolton. What dust there is, however, Juno will try to study. "We're using the dust impacts for science; we have cameras onboard and plasma wave instruments that will detect when the solar panels are getting hit by dust. We'll use that to learn about the dust, but a large pebble might hit us."

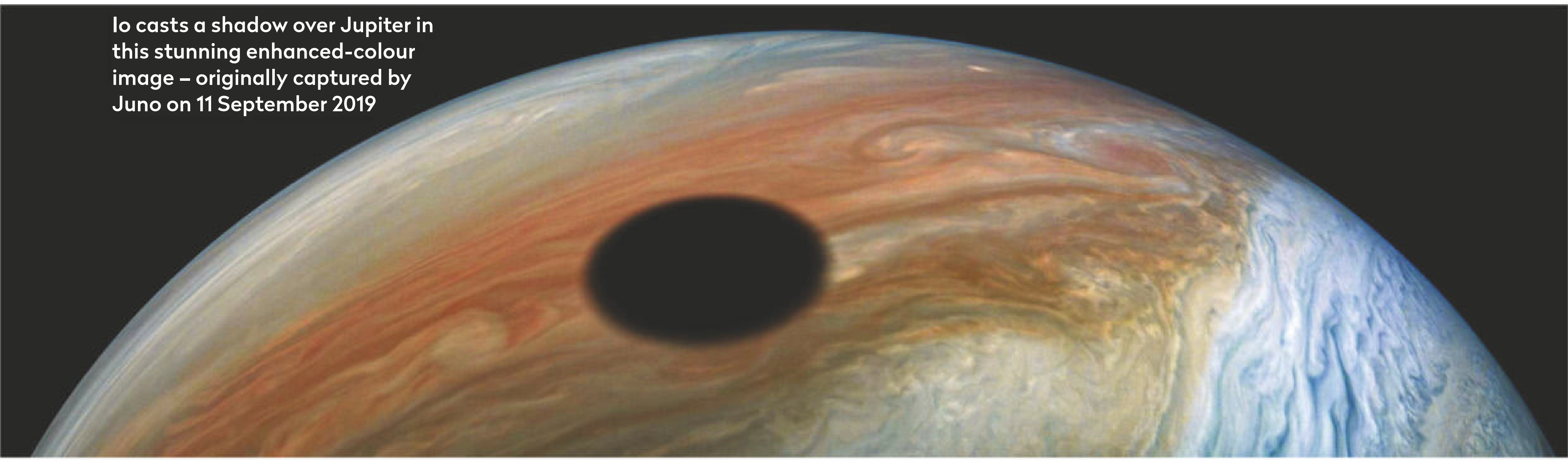
By that point in the mission, it's expected Juno will be running out of the fuel it needs to keep its antenna pointed towards Earth and able to transmit back data. That's if it makes it to that point – though Juno is faring well against the radiation, it is still constantly being bombarded and cannot hold out forever.

The initial plan for ending the Juno mission was to crash the spacecraft into the clouds of Jupiter, to make sure it doesn't end up contaminating the potentially habitable Europa. Fortunately, the new path will take it well within Europa's orbit. While that means it won't be purposefully crashed, the spacecraft won't avoid its meeting with Jupiter's atmosphere entirely. Eventually its path will collide with Jupiter and it will burn up in the atmosphere, meeting its end at the hands of the planet whose secrets it has spent years uncovering.



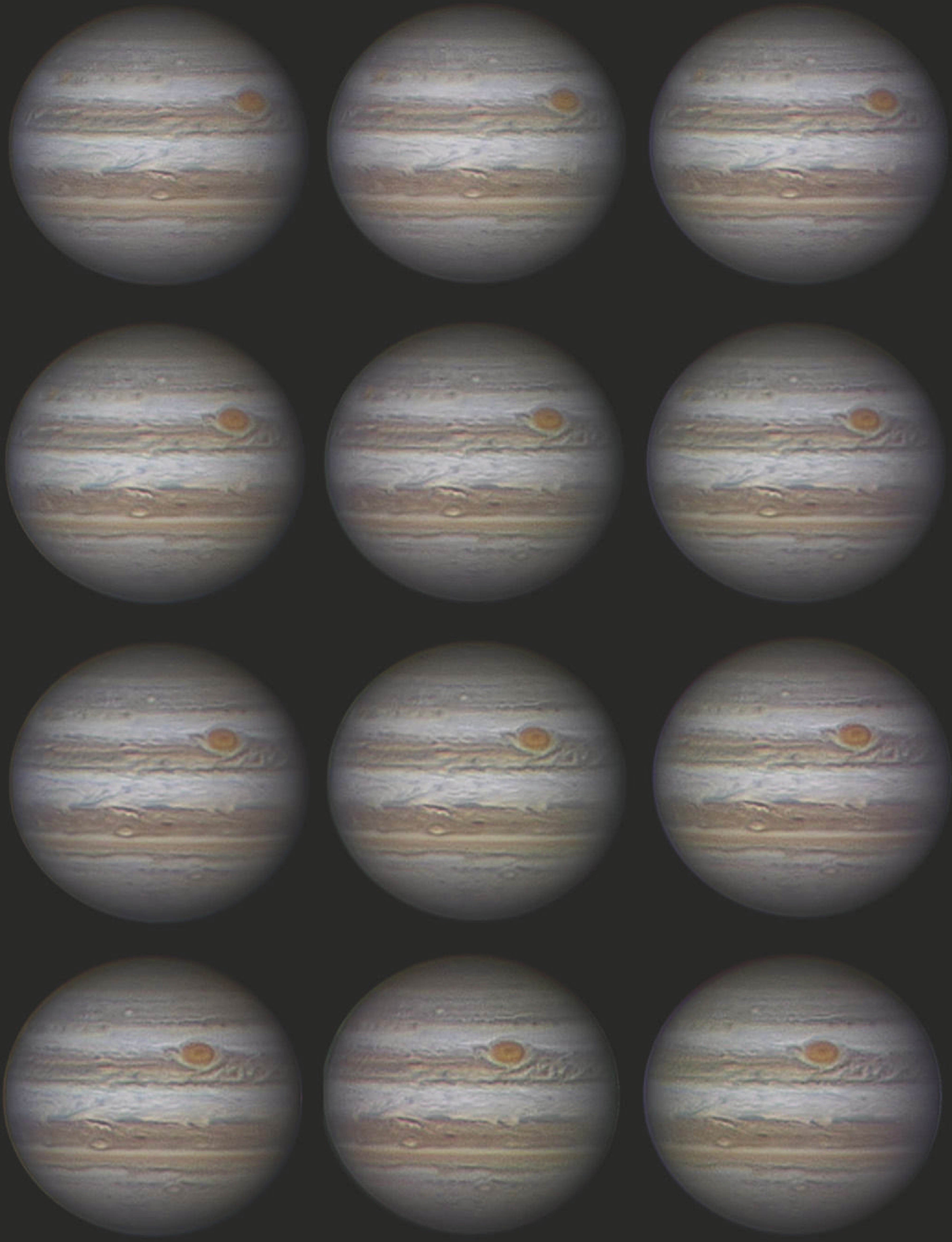
**Images of Ganymede, taken during Juno's flyby of the moon on 7 June 2021, reveal its surface features in remarkable detail**

**Dr Ezzy Pearson** is *BBC Sky at Night Magazine*'s news editor. She has a PhD in extragalactic astronomy



**Io casts a shadow over Jupiter in this stunning enhanced-colour image – originally captured by Juno on 11 September 2019**

Astronomers have a whole range of useful tools at their disposal to capture accurate information about the ever-changing features on the gas giants...

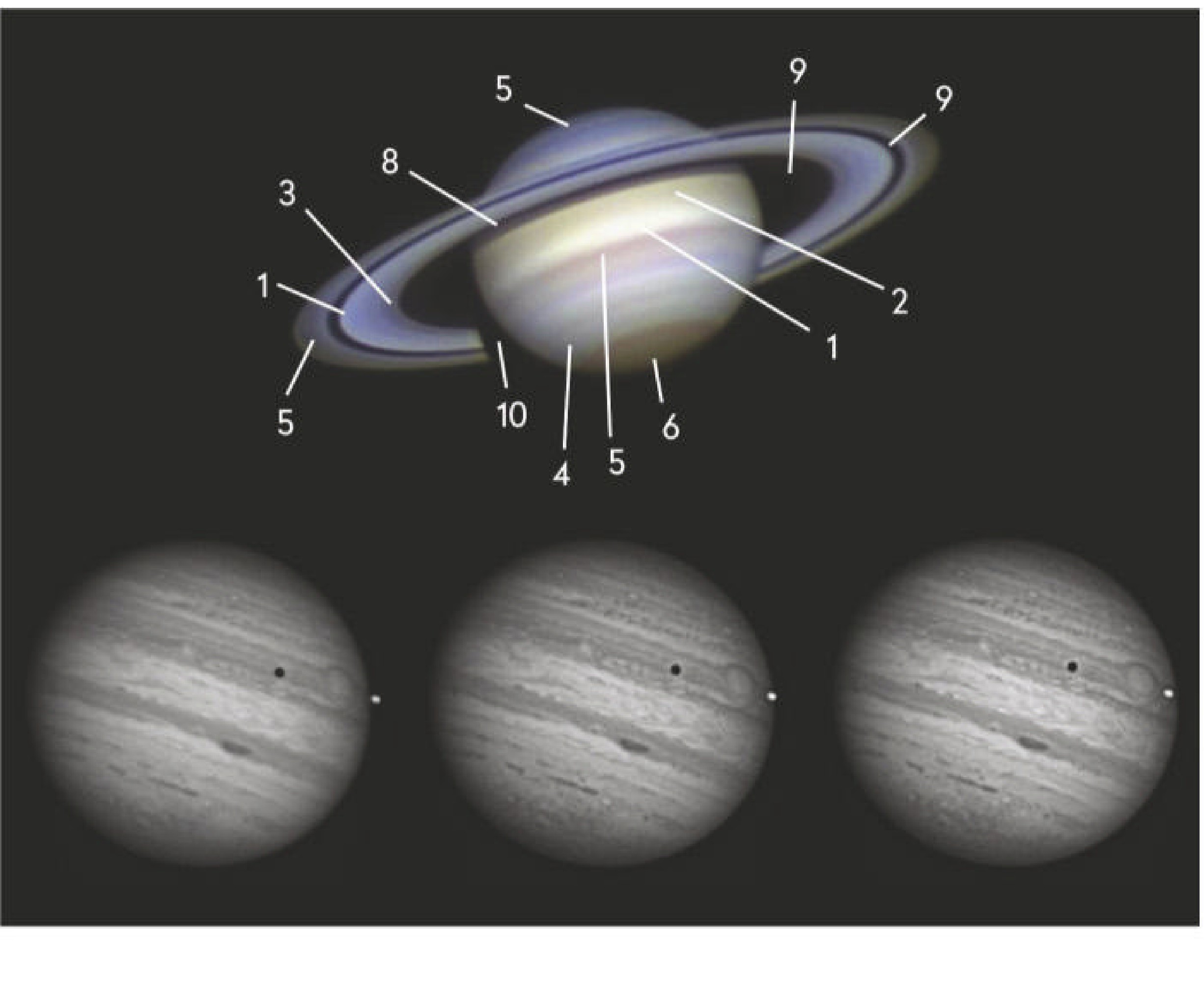



ALL PICTURES: PETE LAWRENCE

# Giants at OPPOSITION

With both Jupiter and Saturn at opposition this month, **Pete Lawrence** looks at how to best gather valuable details about them with your observations

When Earth is directly between the Sun and another planet, that planet is at opposition. This is a great time to view as the planet appears at its largest and brightest.



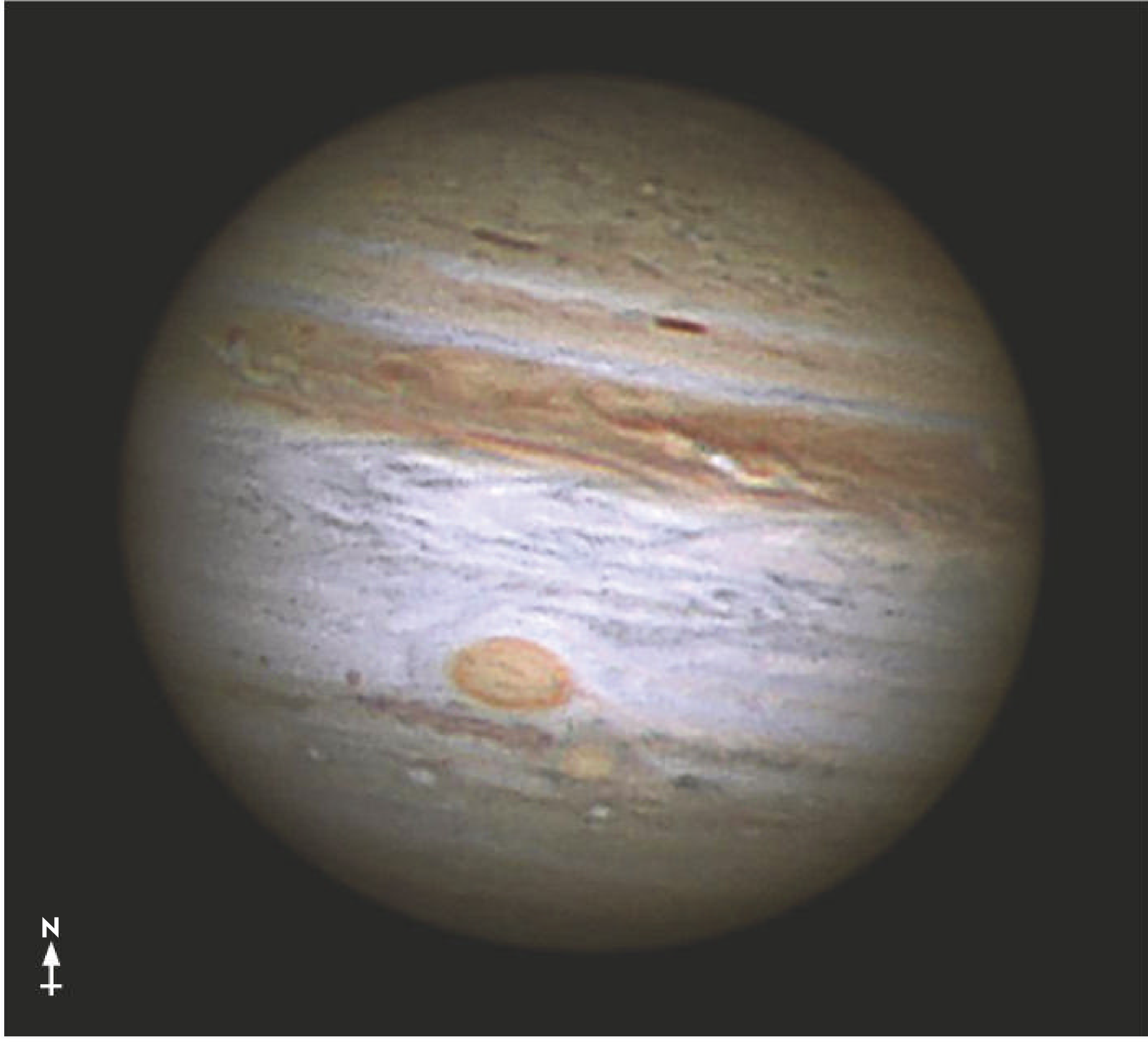

◄ **...whether it's to evaluate the visual brightness of Saturn's different regions (see box, page 71), or to capture a shadow transit in progress on Jupiter's disc**

Gas giants Jupiter and Saturn are both coming to opposition in August and are impressive to view through a telescope for different reasons. Jupiter's dynamic atmosphere shows lots of detail and changes markedly over time. Saturn's atmosphere is subtler, but still has the potential to surprise. And, of course, although Saturn's globe doesn't show the drama present on Jupiter, its rings are a constant draw. Over previous years, both planets have appeared low from the UK, which has made observing them harder. The conditions are now slowly changing and it's a great time to discover how to make scientifically useful observations of them.

## Observing the gas giants

Despite their great distances, Jupiter and Saturn are physically large enough to appear bright and with tangible size through a telescope. Jupiter shows a wealth of detail, which is fascinating to record, either by sketching or imaging. As it rotates in less than 10 hours, you don't have to wait long for its appearance to change. Indeed, wait too long and the planet's fast rotation hides features and reveals new detail.

Saturn rotates quickly too, but it's a different world in terms of visual appearance. Indeed, Saturn's banded ►




▸ atmosphere is shrouded by a haze layer of ammonia clouds, making it hard to see detail. Here, visual and imaging skills need to be honed as much as possible. One way to accomplish this visually is to make intensity estimates for different parts of the planet's disc and rings (see box, page 71). Also, if you can image the planet, you'll find that animation can help to emphasise subtle features on the edge of visibility.

## Atmospheric variations

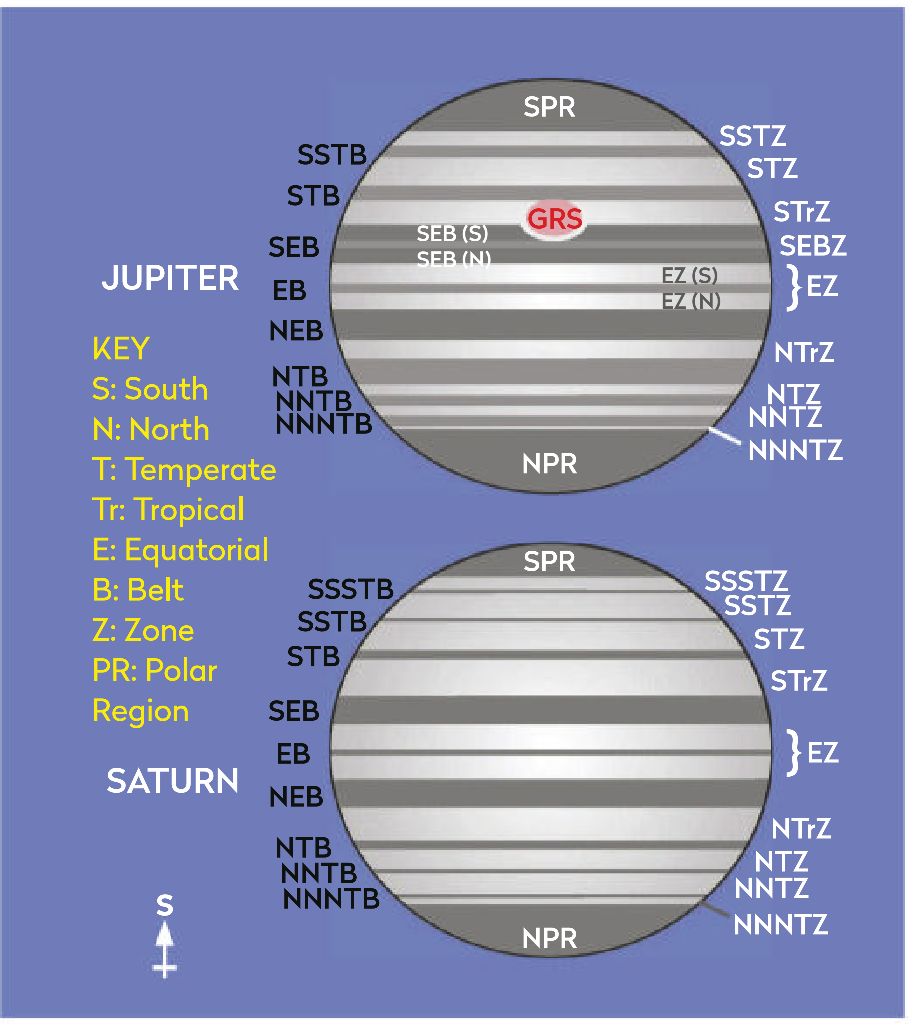
When we look at Jupiter and Saturn through a telescope, we're looking at their atmospheres. Jupiter's is most distinctive, appearing as a series of light and dark banded regions. The famous storm known as the Great Red Spot (GRS), nestles into a scalloped-out region on the southern edge of the South Equatorial Belt (SEB). The atmosphere is rich in shorter-lived phenomena too, such as light and dark spots, festoons and barges. In addition, the visibility and appearance of belts and zones varies over time. In 2010, when the SEB disappeared completely, the GRS appeared odd as it floated, detached, around the planet.

Saturn has many belts and zones, but they are subtle and can be difficult to identify uniquely, whether visually or within images. Saturn's atmosphere does exhibit intricate detail but thanks to a high haze layer surrounding the planet, this detail is difficult to pick out. Bright, light-coloured storms do occur in Saturn's atmosphere from time to time. These can become quite extensive, so it's important to make accurate recordings of their estimated size and changes in shape. Large, long-lived Saturnian storms may spread until they virtually encircle the globe.

Jupiter and Saturn's coordinate systems are equivalent to Earth's latitude and longitude. However, as there are no fixed surface features to use as anchor points, longitude-zero is more complex to define than the Greenwich Meridian, Earth's line of zero longitude. Latitude is easy: measured in degrees, it varies from

▲ **Jupiter's South Equatorial Belt (SEB) vanished mysteriously in 2010, leaving the Great Red Spot to appear as if it was floating alone around the planet**

PETE LAWRENCE X 4, DIETER RETZL/CCDGUIDE.COM




▲ **South-up views of Jupiter (top) and Saturn (below), showing the distributions of belts and zones**

# Observing and reporting impacts

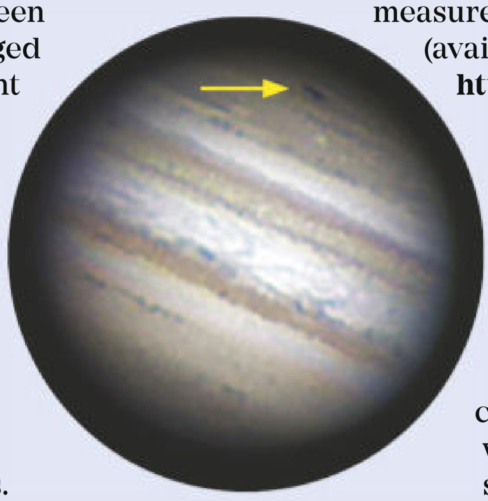
## Keep an eye out for asteroid strikes on Jupiter

The gravitational pull of the gas giants inevitably leads to asteroid impacts. Those large enough to leave a mark are infrequent, but several have been reported and imaged on Jupiter in recent years (none have been reported on Saturn to date.)

As amateurs observe and image the planets regularly, they are the ones most likely to see and report such events. If it's a big impact that leaves a 'scar', professional observatories may divert busy schedules to take a look too. So it's important to report an impact site's location accurately.

It takes experience to make a visual-only impact claim, but if the impact has been imaged, it's easy to locate using WinJupos's measurement scheme (available for free at **http://jupos.org**).

A non-scar impact typically appears as a brief flash. Impacts may occur when you're looking away, so post-capture analysis with specialist software, such as DeTeCt, can help. If you want to follow this route further, look at the Planetary Virtual Observatory and Laboratory (PVOL) at **http://pvol2.ehu.eus/psws/jovian_impacts**.



▲ **Jupiter with an impact scar, taken on 25 July 2009**

# Using filters on the gas giants

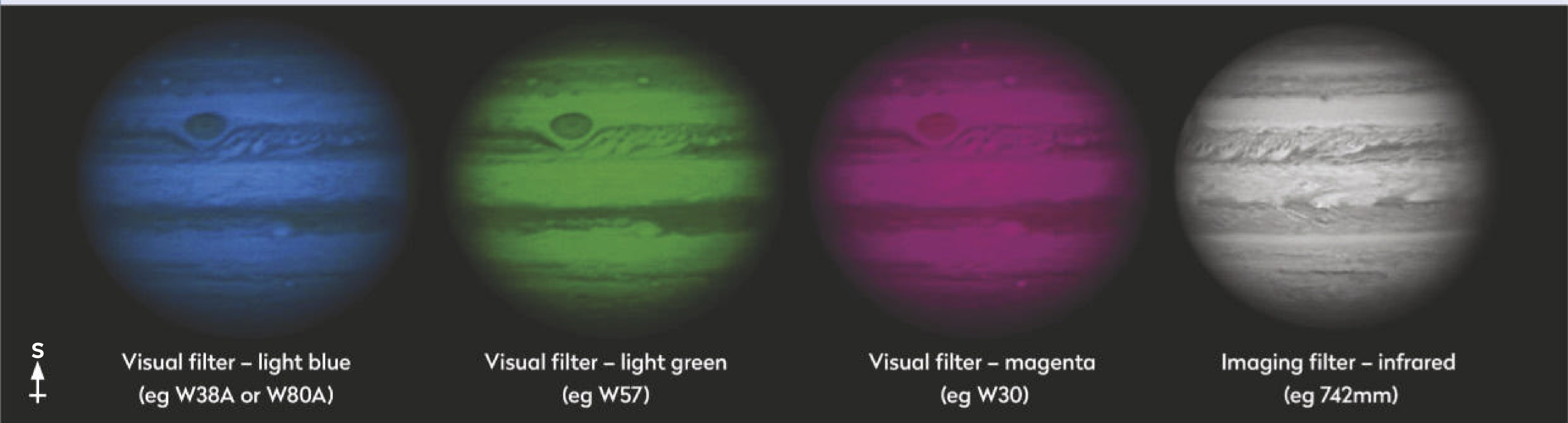
Specific colours and wavelengths will enhance your view of Jupiter and Saturn

Filters can be used to enhance both visual and imaging sessions. The Wratten (W) scheme is commonly employed for visual planetary observation, with filters normally identified by 'W', followed by a number and sometimes a letter.

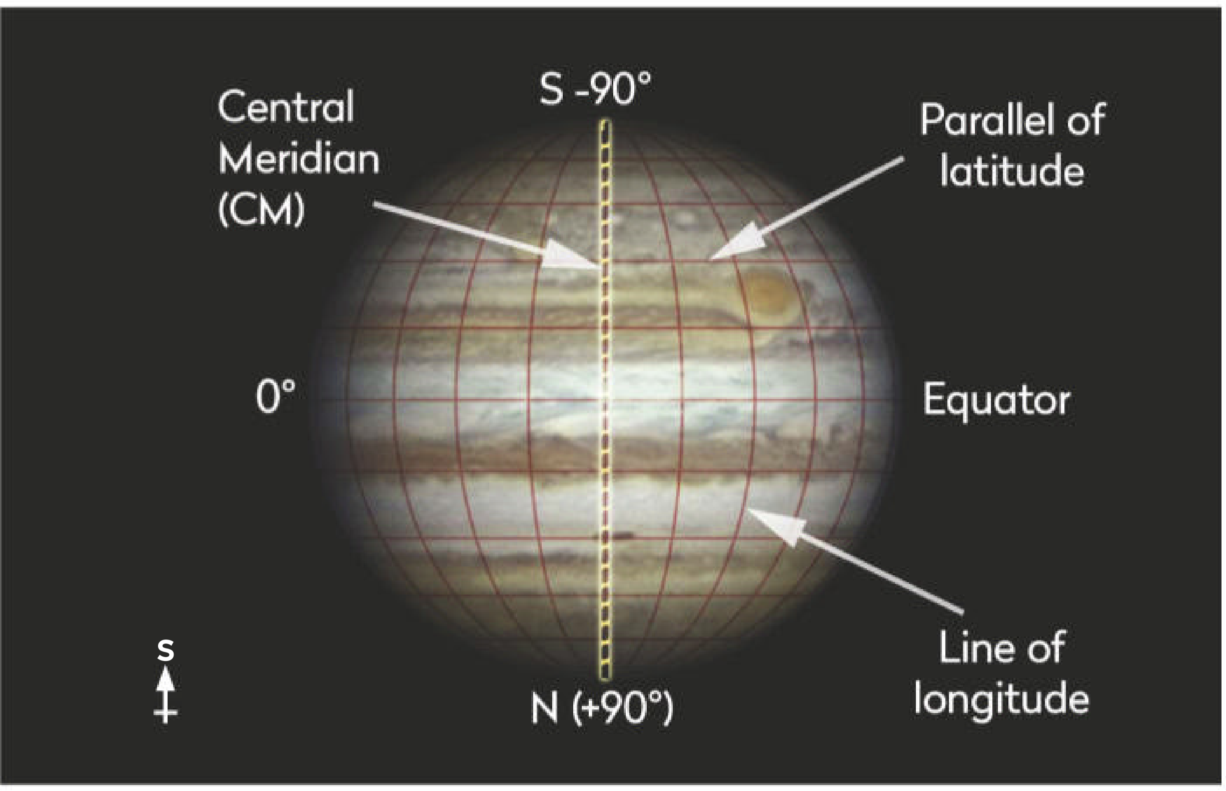
Visually, a light blue filter (W38A or W80A) enhances contrast within brighter zones and draws out detail in atmospheric clouds. Light green (W57) and blue (W47) helps to darken brown-hued belts. A W57 light green or a magenta (W30) filter also helps highlight Saturn's rings. Using a W30 filter, meanwhile, will brighten white ovals in Jupiter's atmosphere.

When imaging, mono camera setups work best for filter work. Full colour images are made by imaging through red, green and blue imaging filters and combining the results. Infrared (IR) pass filters produce high-contrast results, great for showing definition. Some colour cameras have good IR sensitivity and can be used in combination with such filters.

Speciality filters, such as those centred on the methane absorption band ($CH_4$), produce valuable results for Jupiter. Centred on a wavelength of 890nm and with bandpass windows typically less than 15nm across, light is at a premium with this filter making it more suitable for larger instruments. A $CH_4$ filter brightens high-altitude atmospheric features.




▲ Filters can be used to enhance features on Jupiter and Saturn for both visual and imaging setups




▲ The coordinate system on Jupiter uses a similar latitude system to Earth, but longitude is determined from a timed Central Meridian (CM)

0° at the equator to 90° at either pole. By convention, northern latitudes are positive, southern negative.

Longitude determination is done by timing. Visualise an imaginary line running from the planet's north pole to its south pole, and this imaginary line is known as the planet's Central Meridian (CM). As the rotation period of each planet's atmosphere is known, it's possible to define the Prime Meridian (zero longitude) as the longitude at the CM at an agreed, defined start time. As the planet rotates, the CM longitude increases until it's reset as the chronological Prime Meridian is reached again, one rotation later.

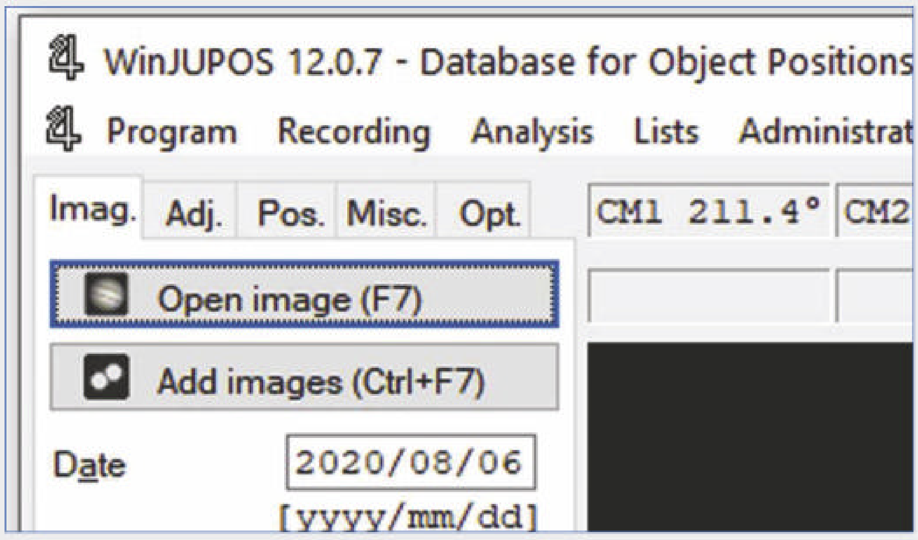
A complication occurs due to the equatorial regions rotating faster than the rest of the atmosphere. This is addressed by dividing regions into two longitude zones: System I is used for the equatorial region between latitudes +10 and –10, while System II covers everything else. However, a further longitude system also exists, known as System III, which reflects the time it takes for the planet's magnetosphere to rotate. Although System III reflects the official rotation period of each planet, amateur astronomers normally use System I and II.

## Keeping track

As Jupiter and Saturn rotate quickly, over several nights it's relatively easy to see a specific atmospheric feature passing the CM. For small features, accurately recording the time (in Universal Time) when this happens allows you to determine the longitude of that feature. If you make longitude measurements of the same feature over a long period of time, ranging over months or even years, you will be able ▸

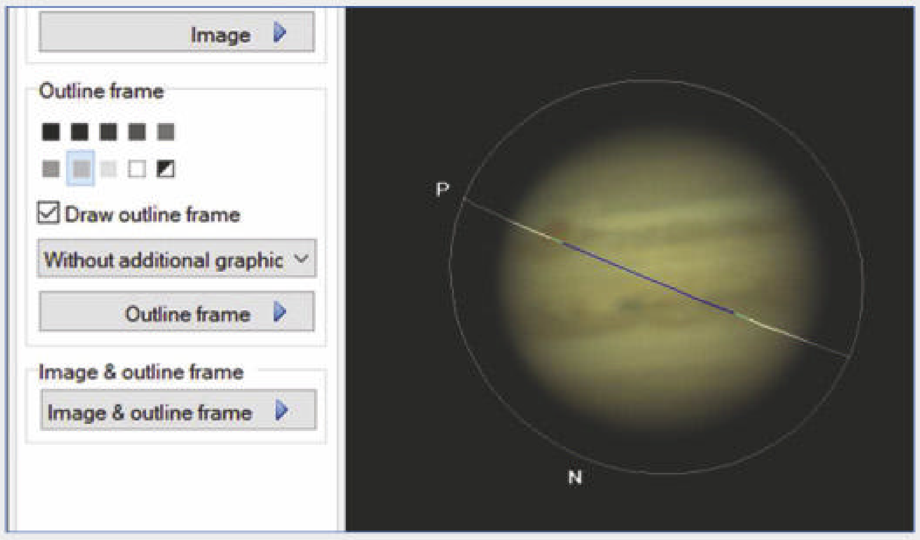
# Step by step: how to use WinJupos

Thanks to its many measuring tools, WinJupos is the software equivalent of a Swiss Army Knife for planetary observers. Here we use it to show the width of the Great Red Spot



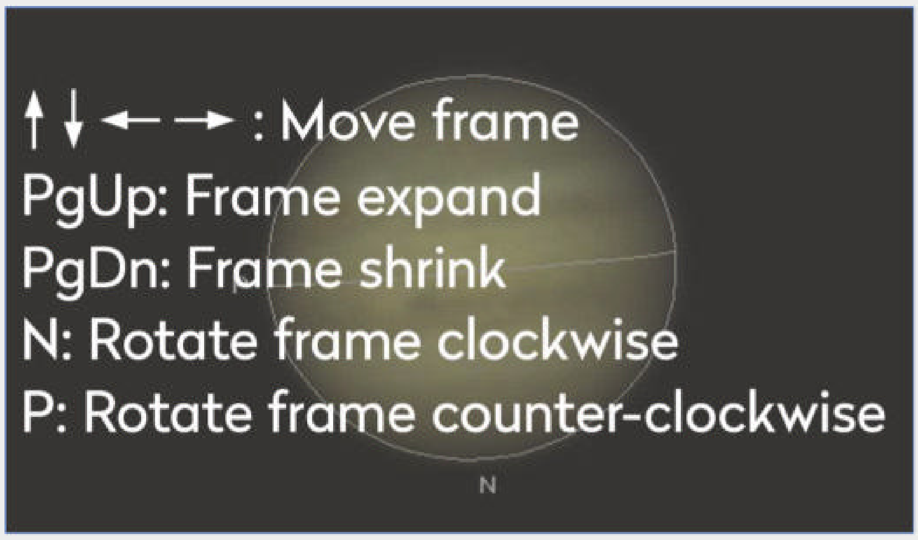

## Step 1

Download WinJupos from **http://jupos.org**. Run the freeware and select 'Celestial Body > Jupiter' under the 'Program' menu. Next, under the 'Recording' menu, select 'Image measurement...'. In the subsequent window click 'Open image' (F7) and select your image.



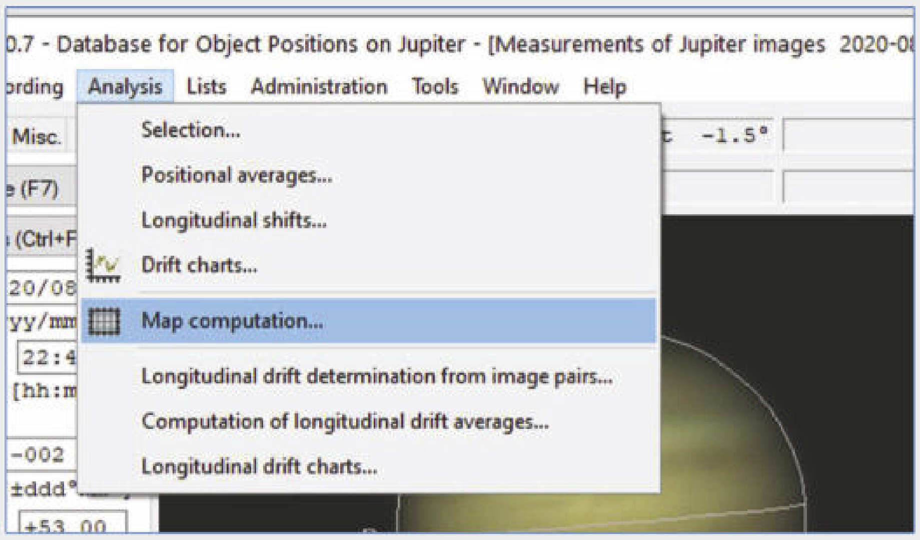

## Step 2

Ensure the 'Date' and 'Time' for the image are correct in the 'Imag.' tab, before selecting the 'Adj.' tab (to the immediate right of the 'Imag' tab). Select the correct 'Channel' (F9) value for the image and ensure 'Draw outline frame' is selected.



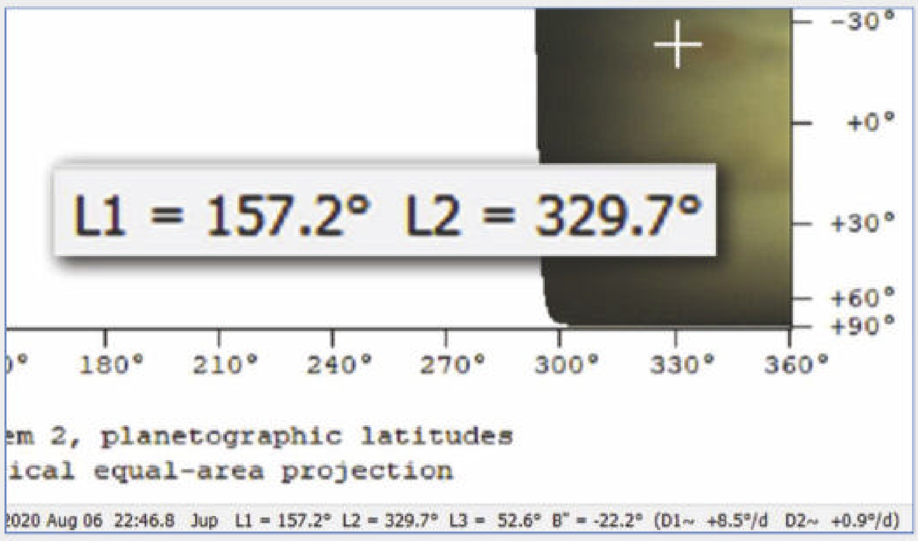

## Step 3

The correct frame orientation and alignment is important. 'Outline frame' > 'Automatic detection' may work, otherwise use the cursor arrow keys to move position, 'PgUp'/'PgDn' to magnify/shrink and 'N' and 'P' keys to rotate clockwise/counter-clockwise.



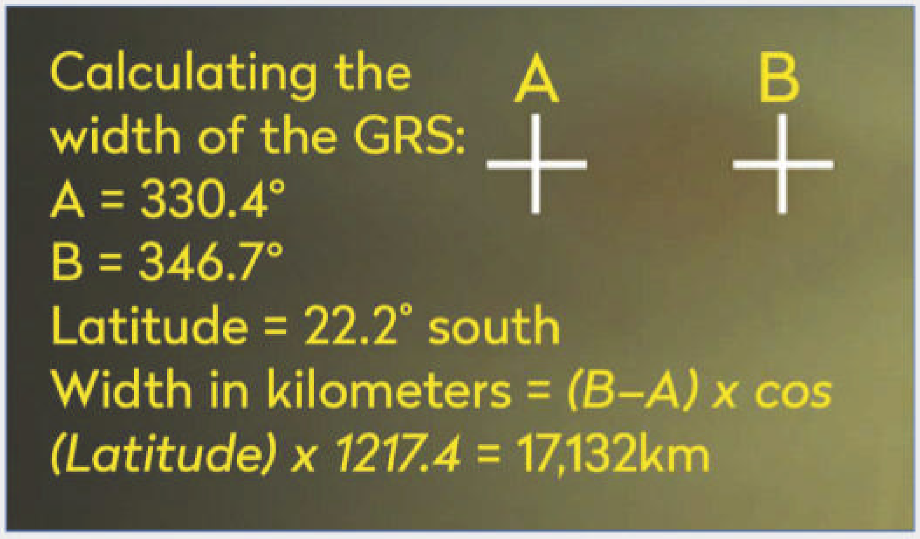

## Step 4

With everything set correctly, click 'Save' (F2) from the 'Imag.' tab and save the 'Image measurement' file. Next, select 'Analysis' > 'Map computation...' and then click on 'Add' from the dropdown 'Edit' menu.




## Step 5

Click 'Compile map' (F12) to generate a map in WinJupos. You will notice that the latitude (B) and longitude (L1, L2 and L3) values at the position of your mouse cursor are displayed in the status bar.




## Step 6

Measuring the longitude values of the preceding and following edges of the Great Red Spot (GRS) using L2 (System II), along with its central latitude, allows you to calculate the physical width of the GRS as 17,132km.

# Making intensity estimates

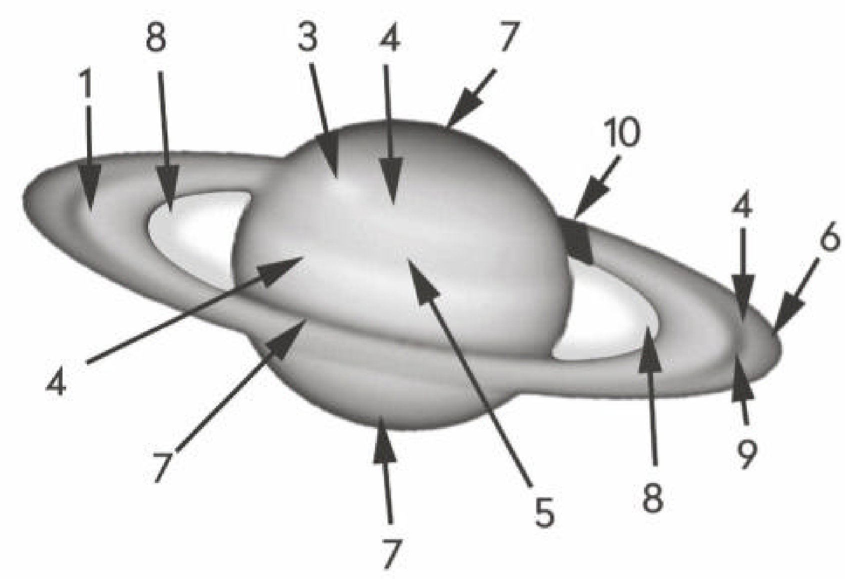
## How to make accurate visual brightness evaluations in different sections of Saturn

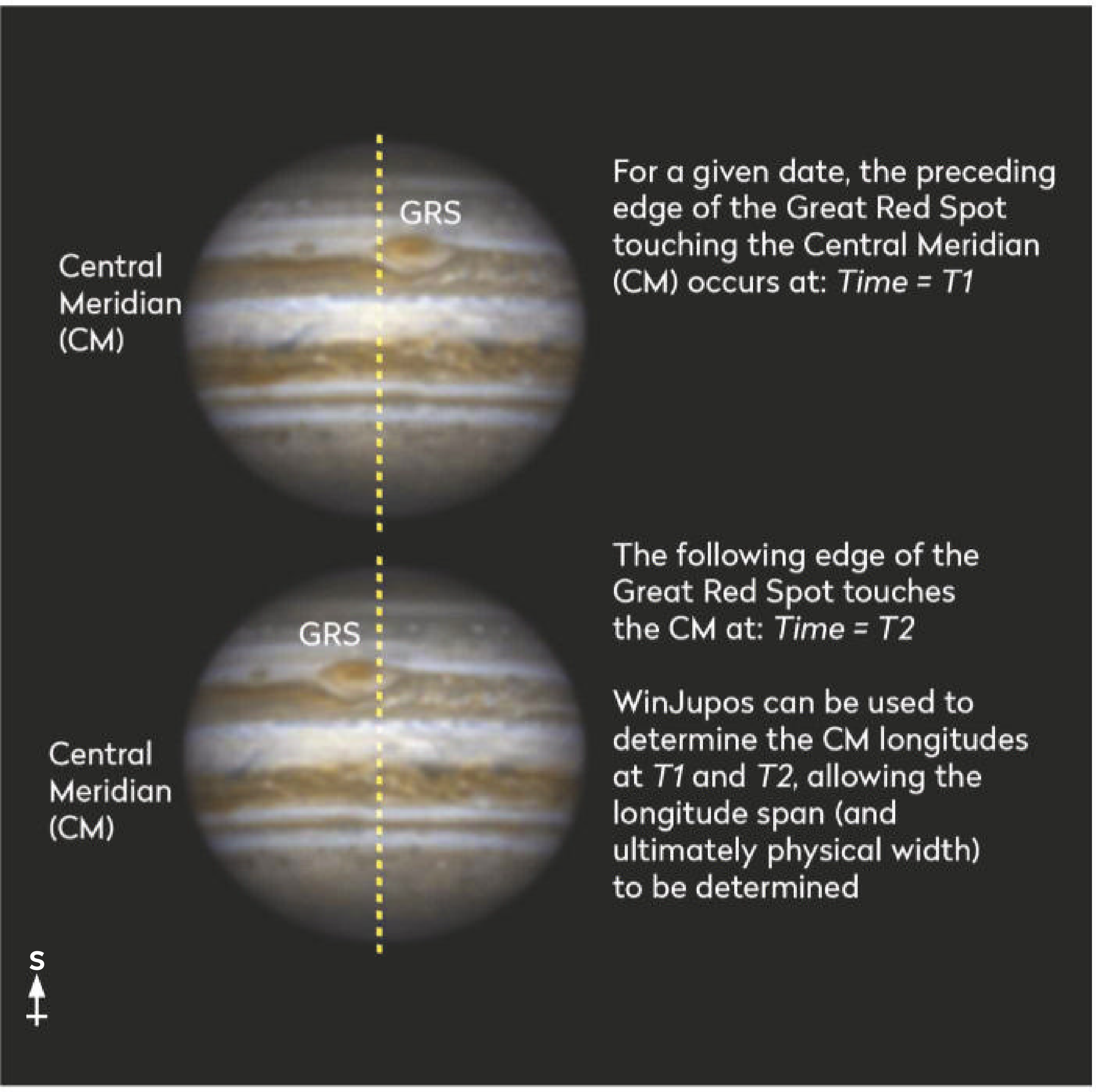
Using a telescope and your eyes, intensity estimates can be made of Saturn. You'll need a planetary blank to show the correct outline of the planet for the observing date. WinJupos can generate blanks by selecting Saturn from the 'Program' > 'Celestial body...' option, before choosing 'Tools > Ephemerides...' and going to the 'Graphics' tab. Make sure the date is set correctly and turn off any textures, etc, to show a planetary outline which can be printed.

At the eyepiece, the intensity estimate is done by dividing the planet into areas of equal brightness. A numeric scale of 0 to 10 is then used to annotate each area according to its brightness, 0 being bright, 10 dark. Intermediate, decimal values may be used if required. In order to calibrate any estimates, two fixed areas are used. The outer part of ring B, the brightest of Saturn's rings, is given an intensity of 1. The dark shadow of the planet's globe on the rings is given a value of 10. In the case of the brightness value, brighter areas may be seen and these should be given decimal values less than one, up to a maximum of 0 for an exceptionally bright region.

Observer bias can be eliminated by first labelling regions brightest to darkest. Once complete, start on a new blank but label darkest to brightest. Although tricky at first, it doesn't take long before making accurate estimates becomes second nature. The technique is also a great way to connect to Saturn visually, forcing you to look at every part of the planet.

**Annotate each area of Saturn according to brightness by numbering them on a scale from 0 to 10**




▲ **WinJupos can be used to determine longitudes of the times (*T1*, top and *T2*, bottom) when the edges of the Great Red Spot touch the Central Meridian**

► to determine how much the feature is drifting within the planet's atmosphere. By plotting time versus longitude you can generate a drift chart to tell you a great deal about how the planet's atmosphere works.

Features with tangible widths can be measured using the planet's rotation. Imagine the leading (preceding) edge of a feature reaching the CM at time *Tp*. The feature's trailing (following) edge will pass the CM at time *Tf*. The feature's width can be determined by converting these to longitudes *Lp* and *Lf* using WinJupos (**http://jupos.org**). The physical width in kilometres is calculated with the following formula:

$$(Lf-Lp) \times 1217.4 \times \cos(\text{latitude})$$

All timings should be done in Universal Time and it's important to use the correct longitude System, I or II.

This brings us to Jupiter's Great Red Spot (System II), an extended feature (see box, opposite). CM timings of its preceding and following edges, along with timings that record its centre crossing the CM, give valuable information. While edge timings give its width, the CM timing reveals its central longitude. Over the years the GRS's physical width changes and its longitude drifts.

If you can master these useful scientific observing techniques, it will help to enrich your planetary observing for many years to come.

**Pete Lawrence** is an expert astro imager and a co-presenter on *The Sky at Night* on BBC TV

The fundamentals of astronomy for beginners

# EXPLAINER

## Noctilucent clouds: an ongoing discovery

**Emily Winterburn** investigates the history of NLC observations


A noctilucent cloud display can be one of summer's most stunning spectacles

Noctilucent clouds (NLCs) are the highest clouds in the atmosphere and we can see them around astronomical twilight in a summer's night sky. The name comes from Latin, meaning 'night-shining clouds', and they occur when the Sun is below the horizon and the clouds are still in sunlight. Although no one as yet fully understands why, this appears to be a relatively new phenomenon first seen in 1885 and with an increased frequency in recent years.

### First sightings

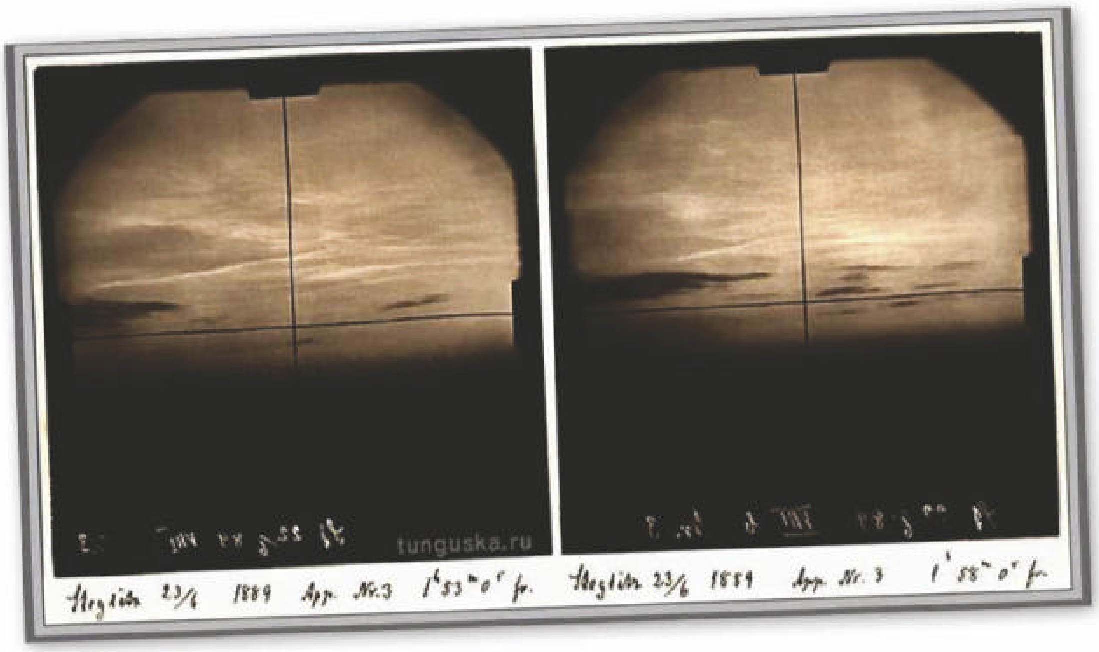
While these clouds can be a spectacular sight, curiously no one appears to have recorded observing them before 1885. Two years earlier, in 1883 the volcano Krakatoa erupted, destroying land, creating tsunamis and causing around 36,000 deaths. The after-effects of the eruption were felt for years and included vivid red sunsets, which were seen across the world as the ash from the volcano drifted and filled the skies. Prepped by the after-effects of this volcano to look more closely at atmospheric phenomena in the night sky, a number of observers began to notice these curious, shining clouds and naturally assumed these, like the deep red sunsets, must be linked to the volcanic eruption.

Thomas Backhouse, an astronomer and meteorologist based in Sunderland, was interested in cloud formation. He had studied lots of different types of cloud, and in 1884 began to notice what he considered to be a new type of cloud which he noted was rather unusual in only being visible after sunset. He kept watching, even after the effects from the volcano began to fade, and in 1885 published a paper on his findings.

At around the same time over at Armagh Observatory in Ireland, the observatory's director, Thomas Romney Robinson, was possibly observing the same thing. He never published his findings but he did note the appearance of "luminous clouds" in his meteorological record books over several decades. These observations were not often in the summer, however, which suggests that they might relate to some other phenomenon.

At first, following Backhouse's publication, it was widely supposed that the clouds were a result of the volcanic ash from Krakatoa, but the clouds persisted even after the volcanic dust settled and the link was eventually disproved in 1926.

Back in the 1880s, astronomers and meteorologists continued to observe and study these new clouds. At the Berlin Observatory in Germany, Otto Jesse took a particular interest, taking the first

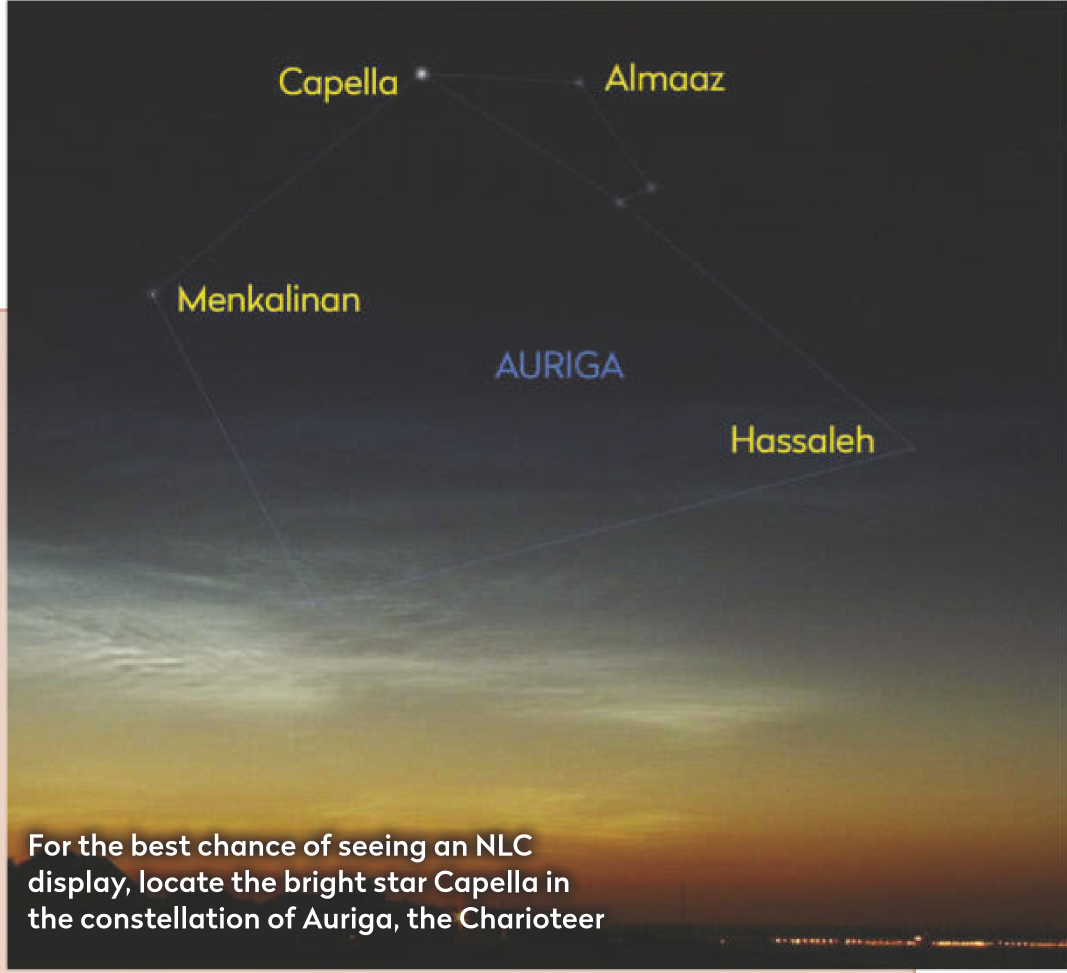


▼ Early photos of noctilucent clouds, as taken by astronomer Otto Jesse in the late 1880s

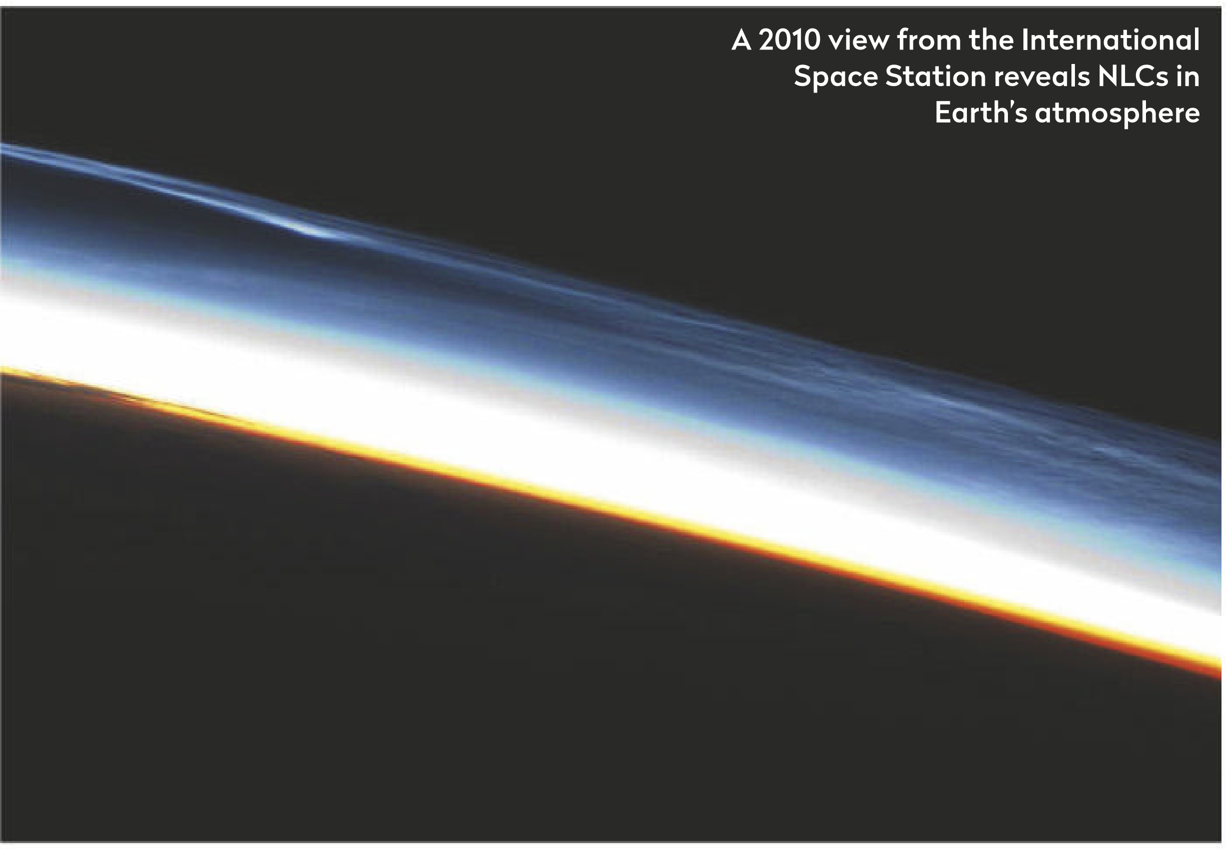
# How to spot NOCTILUCENT CLOUDS

Five top tips for spotting NLC displays

**1.** Look for NLCs in the northern sky, 90–120 minutes after sunset, between the end of May and start of August. They sometimes appear at the same time before sunrise.
**2.** Ensure you're facing the right direction, by looking towards the bright star Capella (Alpha (α) Aurigae) in the constellation of Auriga.
**3.** If you plan to take photographs, use a tripod and an exposure time of between 2 and 6 seconds.
**4.** It's hard to predict the weather but try and choose a day with clear skies.
**5.** Look out for white or electric blue clouds, maybe with a herringbone or rippling sand-type pattern.



For the best chance of seeing an NLC display, locate the bright star Capella in the constellation of Auriga, the Charioteer


A 2010 view from the International Space Station reveals NLCs in Earth's atmosphere

photographs in 1887 and he appears to have even coined the name we still use today: 'noctilucent cloud'. Studying his earlier observations, he concluded that these NLCs first appeared in 1885 and were not visible before this; he then organised a programme of systematic photographs to be taken so further investigations could be made of what and where these clouds were.

NLCs are in fact ice crystals and dust found in the mesosphere (in the upper atmosphere at an altitude of around 80km) that reflect sunlight, but not enough to make them visible during daylight hours. Recent studies suggest the phenomenon may be exacerbated by climate change and the increased concentrations of atmospheric methane. Dust from events such as volcano eruptions and Space Shuttle launches can also make them more likely to occur, showing that Backhouse's initial thoughts weren't quite as wrong as his successors believed.

In 1972, NASA's OGO 6 satellite (the Orbiting Geophysical Observatory) became the first instrument to detect NLCs from space. Today, it is the AIM (Aeronomy of Ice in the Mesosphere) satellite, launched in 2007 that provides us with our most in-depth studies of these clouds. This satellite is dedicated to the study of NLCs and its work over the past 14 years has allowed scientists to forecast when and where NLCs are most likely to be visible.

## Other atmospheres

It would seem that NLCs are not unique to our planet. In 2019, the Curiosity rover on Mars was reported to have seen noctilucent clouds in the Red Planet's sky. More recent observations by the Curiosity rover suggest some of these clouds might be made of frozen carbon dioxide rather than water ice, which may help scientists determine their altitude. Who knows, perhaps the next breakthroughs in research into NLCs will come not from our planet, but from settlers on Mars?


**Emily Winterburn** is is author of *The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy*


NASA's Curiosity rover spotted these NLCs on Mars over Mont Mercou, appearing high in the atmosphere after sunset on 19 March 2021

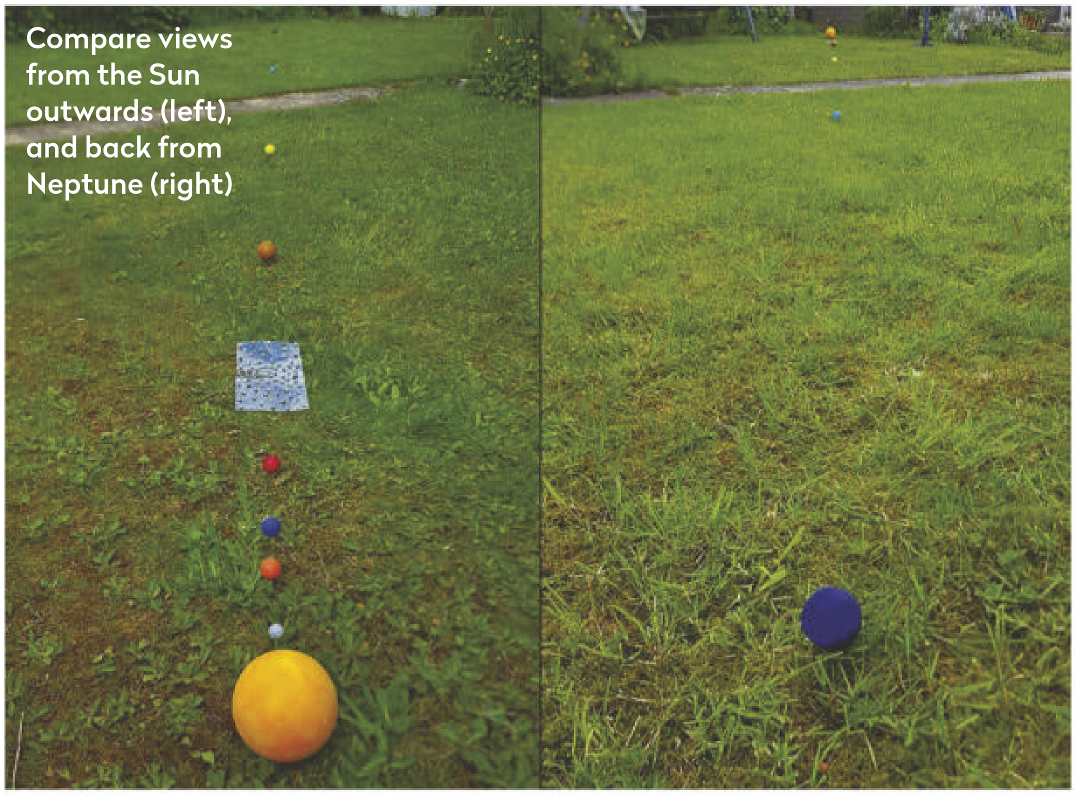
Practical astronomy projects for every level of expertise

# DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

## Make a scale model of the Solar System

Build a model in your garden to reveal the spacing between our planetary neighbours



Compare views from the Sun outwards (left), and back from Neptune (right)

We have all seen diagrams showing the planets of our Solar System orbiting the Sun. Sometimes their relative sizes are shown, but it is impossible to depict the space between them – the orbital distances of each of them from our central star. Our Solar System is huge and the distances involved are difficult to comprehend, so using scale models helps us to visualise this. As the distances are so big, it's almost impossible to have both accurate planet sizes and distances in one scale model: if we scaled the distances based on the Sun's size we used in this model, Neptune would be half a kilometre away! This is not something you can squeeze into most gardens.

For this fun project, we are creating a model that shows the distances at a scale that can fit into a garden or park. The radius of our Solar System has been scaled down to 10m. If our Sun and planets were at the same scale, the Sun would have a diameter of 3cm, but Mercury would be a microscopic 0.1mm, Earth 0.2mm and the largest planet, Jupiter, just 3mm. Obviously we can't replicate that for our model. Instead, we'll be using polystyrene balls of different sizes to show that the planets vary in diameter, but they aren't at any specific scale relative to each other or to the distances. We'll place our planets in a straight line, but they would really extend out by 10m in all directions from our star.

The distance between the Sun and the Earth is 150,000,000km; this is 1 Astronomical Unit (AU). To make the maths simple when calculating the distances for our model, begin by working with a scale of 1 AU to 1 metre. With Neptune at 30 AU, it means the model would be 30m, which is still larger than most gardens. Indeed, we only had 10m to work with. But as this is three times smaller, we got the distances in metres for each planet down to a manageable scale by dividing the AU for each planet by three. You can adapt this calculation to fit your garden, park or green space.

The distances from the Sun for each of the planets are in our downloadable table (see below for instructions). We've also included the inner and outer edge of the asteroid belt. We painted our Sun and planets an appropriate solid colour so they would show up better in photos, but you can add surface features and the rings of the four giant planets.

The end result will give you an invaluable insight into the distances in our planetary neighbourhood.

**Mary McIntyre** is an outreach astronomer and teacher of astrophotography

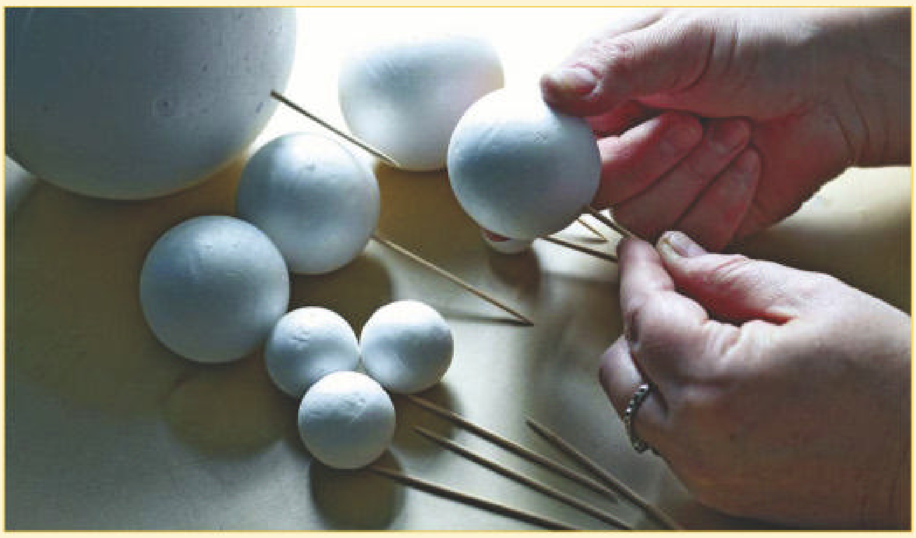
### MORE **ONLINE**

**Download a conversion table (from Astronomical Units to metres) to show the spacing of each Solar System body on the model. See page 5 for instructions**

### What you'll need

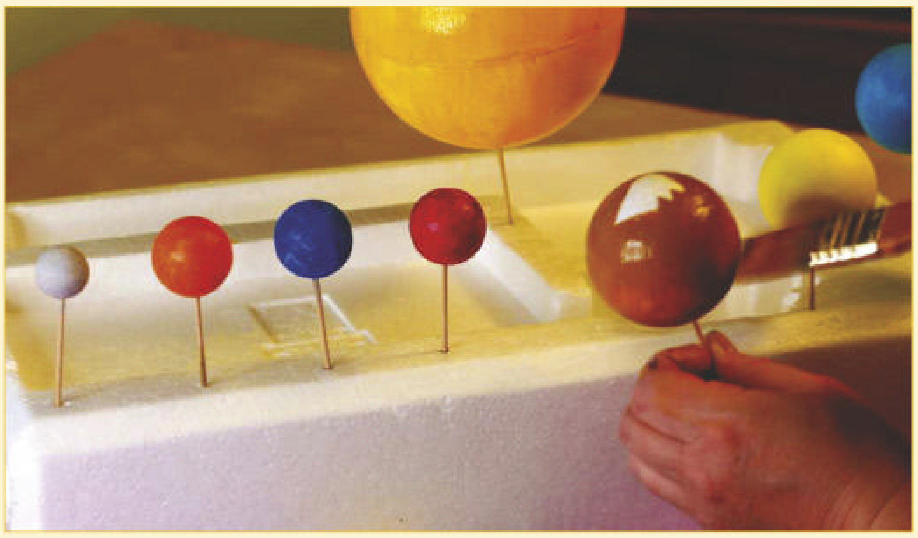
- Nine polystyrene balls of different diameters for the Sun and planets; we opted for the Sun at 11cm; Mercury at 2cm; with Venus, Earth and Mars at 3cm; Jupiter at 6cm; and Saturn, Uranus and Neptune at 4.5cm.
- Cocktail sticks or small wooden skewers – we used these to stick the planets into the ground; water-based paint for each planet.
- Small stone chips and a piece of clear plastic or card to create the asteroid belt – we used a piece measuring 33cm x 15cm and made it by sticking two pieces together with clear tape.
- A long tape measure – if you are measuring by yourself, peg the end of the tape to the ground with a barbecue skewer.

# Step by step



## Step 1

Push a cocktail stick a little way into the balls used for the Sun and each of the planets, making sure you leave enough sticking out to push them into the ground. With the smaller planets, take care not to push the stick all the way through.



## Step 2

Paint the models using acrylic or water-based paint. We painted the Sun yellow, Venus light orange, Earth medium blue, Mars red, Jupiter light brown, Saturn light yellow, Neptune dark blue and Uranus light blue. Stick them into a polystyrene block to dry.

## Step 3

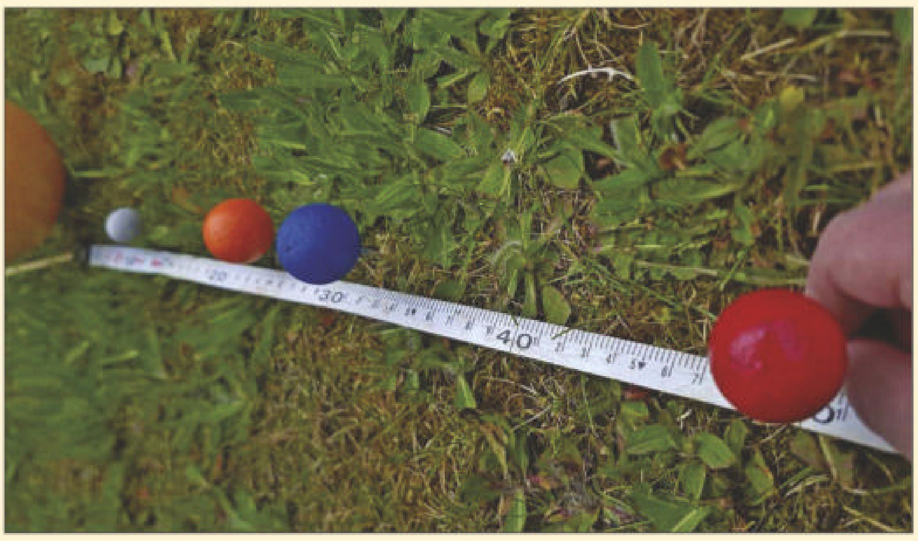
To create the asteroid belt, use PVA glue to stick different sizes of stone chips to the piece of clear plastic or card. Although the asteroid belt covers a vast area, there are huge spaces between each asteroid, so we kept our stones well-spaced.

## Step 4

Choose a large, clear, level section of ground and anchor the tape measure at one end using a barbecue skewer. Then extend it out to 10m, marking the 10m-point with a cocktail stick. You can remove the tape measure once you've added the planets.

## Step 5

Push the Sun into the grass at the start of the measured 10m. Make sure you are holding the stick rather than the ball when pushing into the ground. Each of the sticks will prevent the planets and Sun from blowing around if it's windy.



## Step 6

Push the rest of the planets into the grass at the distances listed in the supplied table (see page 5 for download details) and lay the asteroid belt down 73cm from the Sun. Take time to explore the model and appreciate the vastness of our Solar System.

Take the perfect astrophoto with our step-by-step guide

# ASTROPHOTOGRAPHY CAPTURE

## Imaging the Perseid meteor shower

How to pair a planetary camera and CCTV lens and capture the peak of the Perseids

▲ **Get your setup ready for the peak of the Perseids on the night of the 12/13 August between 23:15-03:20 BST (22:15-02:20 UT)**

Clear skies may produce plenty of bright Perseid trails, but capturing one on camera isn't easy. This month we're looking at how to record meteor trails using a high frame rate camera, the sort normally used to image planets.

These cameras have good sensitivity and the option to take really short exposures. However, we're ignoring this and extending their capability to record wide-angle shots of the stars using longer than normal exposures, like we would do with a DSLR.

There are lots of planetary cameras on the market and many can be used for this task. A lens will be needed and these can be obtained through many online sources. A fast C-mount CCTV lens is required, along with a T-thread to C-mount adaptor (the T-thread being the thread in your camera into which you screw a lens). Once the adaptor is in place, the lens can be screwed directly into the camera body.

The field of view is determined by the lens's focal length and it's recommended to choose a lens with a focal length below 4mm to give good sky coverage. The lens aperture should be fully opened to let the maximum amount of light in.

You'll need to mount your camera body – on a tracking mount and tripod if you have them. Some models have camera-threads on the body for this but, if not, an impromptu platform where the camera can point directly up should be fine. Just make sure the camera can't accidentally move about.

Accurate focus may be achievable by using the lens's own adjustment, but you may also need to make rough adjustments to the lens-chip distance by screwing the T-thread to C-mount adaptor in or out to get the lens within the approximate focus range first.

Planetary cameras require a computer and control software to work. If you're outside, a cover or box placed over the computer will prevent moisture building up, but be careful not to block cooling vents. The control software is down to personal preference; popular choices include SharpCap and FireCapture.

Focus can be achieved by setting the camera exposure to a second or two and using a bright star. Take your time to get this as sharp as possible. It's advisable to view a clear unobstructed sky if possible. As short focus CCTV lenses can give a good field of view, pointing directly up is a good choice.

Just like a regular lens, it's important to make sure the lens doesn't mist over on a damp August night. A quick check with a torch will suffice. A 12V hairdryer can be used to rapidly get rid of any misting.

Try and make setup tweaks early, so you're ready for the Perseid peak on the night of the 12/13 August.

**Pete Lawrence** is an expert astro imager and a presenter on *The Sky at Night*

**Recommended equipment: Planetary camera, a wide-angle CCTV lens**

▸ **See the 'Perseid Perfection' feature on page 28 and 'The Sky Guide' on page 46 for more details**

**Send your images to:**
**gallery@skyatnightmagazine.com**

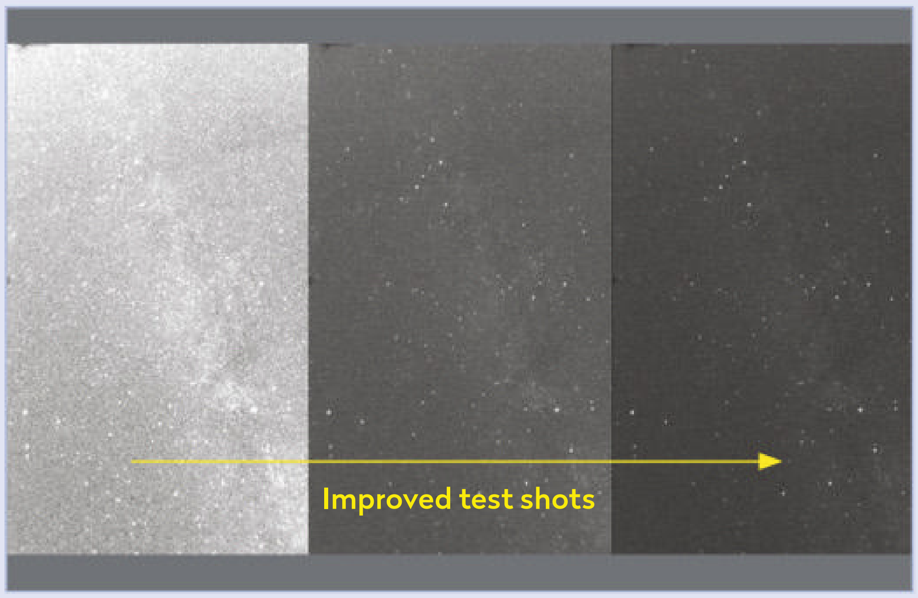
# Step by step

## STEP 1

You'll need a fast, short focal length CCTV lens, available from many online sources. A C-mount to T-thread adaptor will also be required, the T-thread screwing into the camera housing. Avoid screwing it completely into the camera to allow leeway for any rough focusing. Ensure the lens aperture is fully open.

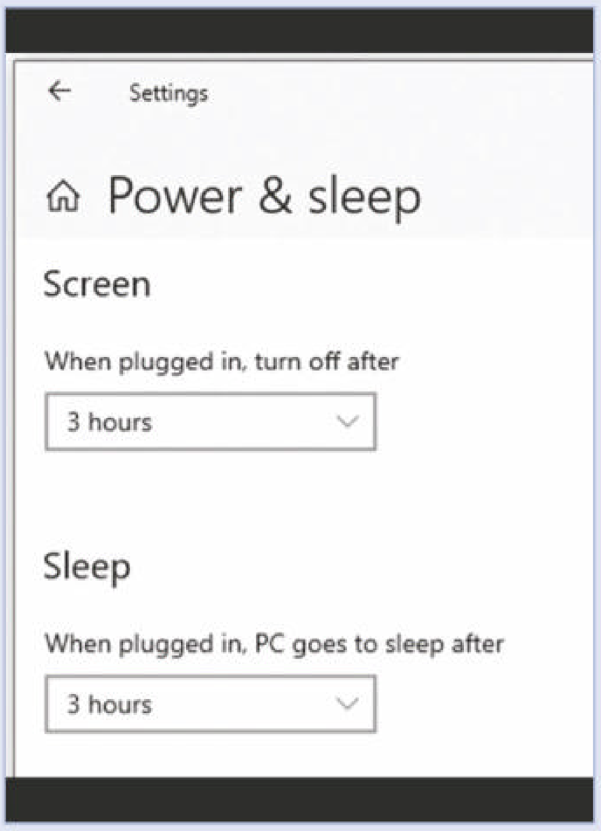
## STEP 2

On a clear night, fit the lens and point the camera at a bright star or planet. It's a good idea to put the lens focus ring in the middle of its range. Screw the lens adaptor in/out to achieve rough focus; electrical tape can be used to secure the adaptor in this position. Finally, fine focus using the lens ring.



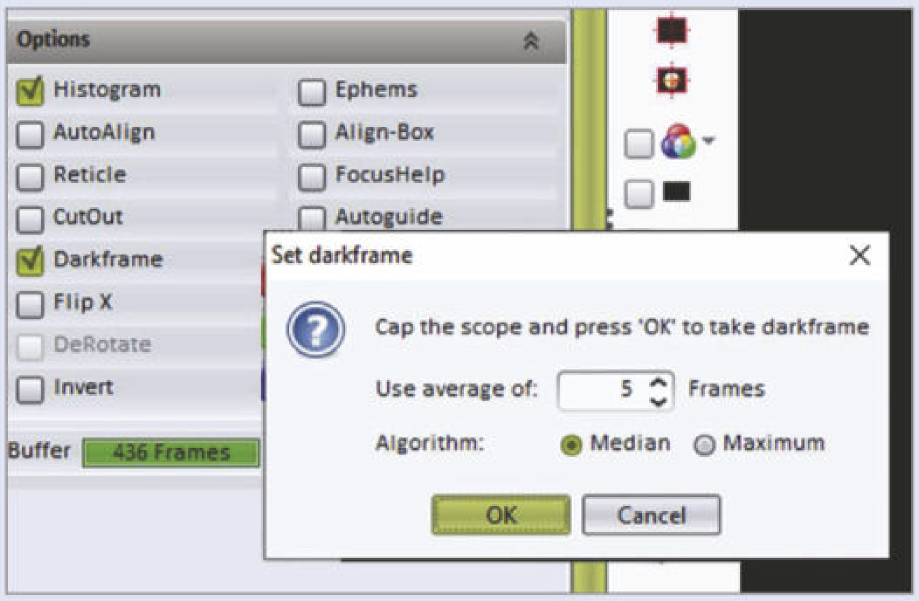

## STEP 3

Using your selected control software, adjust the camera to a high gain setting. Start off at 50-75% gain. The final value will depend on your sky quality and camera noise characteristics. Set the exposure to say, 5 seconds, and take a test shot. Examine its quality. If it's really bright or noisy, consider reducing the gain.



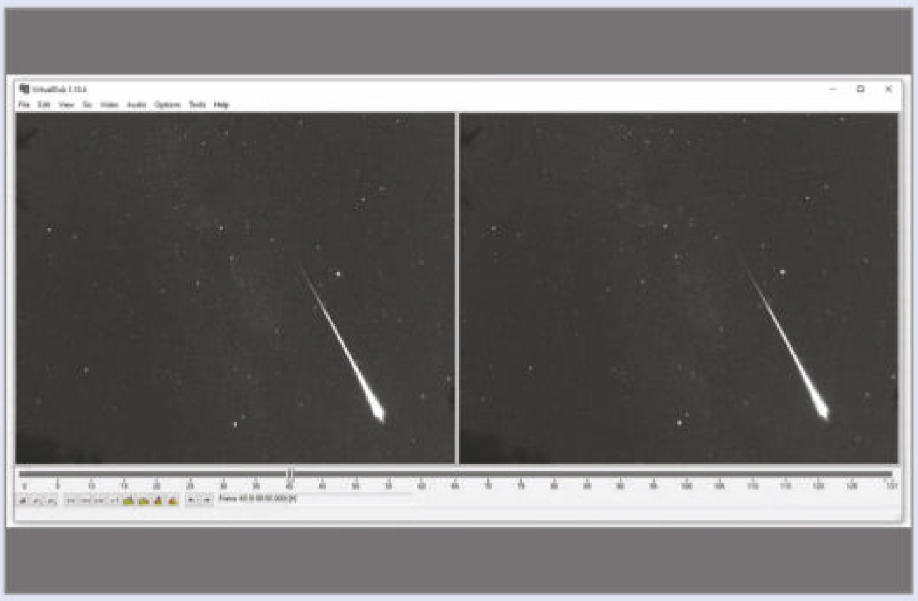

## STEP 4

Check your computer's power settings and adjust if needed so it will remain on for at least as long as the session you intend to cover. Choose your exposure setting. Here, longer exposures are simply to reduce the frame count overhead; 5 seconds generates 720 frames per hour, 2 seconds generates 1,800 frames per hour. We'd recommend somewhere in this range.




## STEP 5

If your control software permits, take a calibration dark-frame before recording. This requires you to cover the lens before the software automatically takes a number of frames, which are averaged and subtracted from the live video capture frames. Ensure the field of view is obstruction-free, and hit record.



## STEP 6

Record in 30-60 minute blocks, using the transition period to check for lens misting and that everything works. Post capture, watch the result with video playback software. VirtualDub utility (**www.virtualdub.org**) is perfect, allowing you to step through each frame and copy any trails to an editor for later analysis.

Expert processing tips to enhance your astrophotos

# ASTROPHOTOGRAPHY PROCESSING

## APY Masterclass

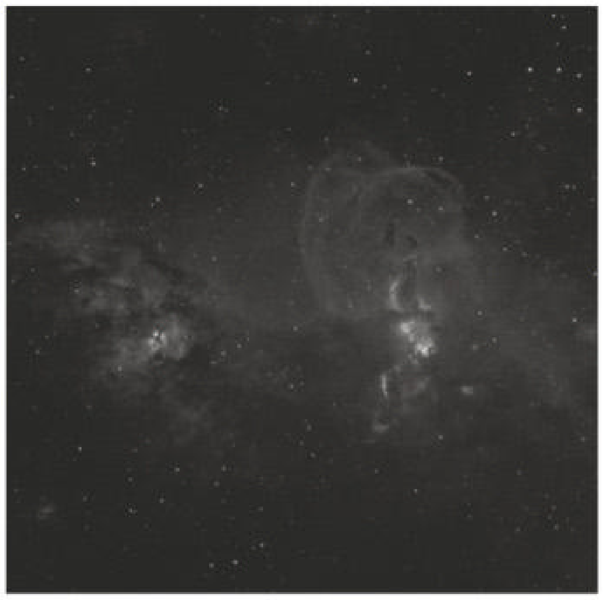
## Bring out a nebula's fiery features

Use stacking software and a 'bushfire' colour palette to enrich detail

**Astronomy Photographer of the Year**

Advice from a winning entrant in the 'Stars and Nebulae' category

'Cosmic Inferno': the impactful image of emission nebula NGC 3576, with its distinctive 'Statue of Liberty' feature clearly visible



▲ The RAW image is calibrated to reduce unwanted artefacts and shadows

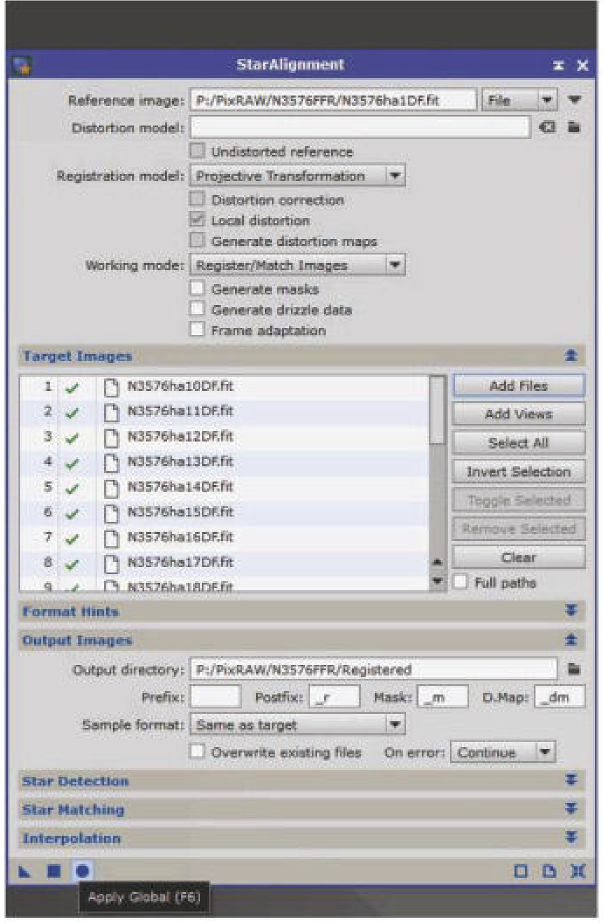
My winning entry in the 'Stars and Nebulae' category at the 2020 Astronomer Photographer of the Year competition is entitled 'Cosmic Inferno'. It features the emission nebula NGC 3576, one the most intriguing nebulae in the southern skies. It has striking features, with great loops of ionised gas that stretch over 100 lightyears into the vacuum of space. Indeed, astronomers have identified polycyclic aromatic hydrocarbons within NGC 3576, hydrocarbons being an essential component for the formation of the earliest life on Earth. And 3.7 billion years after life first appeared on our planet, the bushfires of 2019–20 would raze the ecosystem across vast swathes of the Australian landscape of life – something alluded to in the title I gave to the image.

My original intention was to take a colour image of NGC 3576 using my Alluna RC16 telescope fitted with a monochrome 4k x 4k SBIG CCD camera, a combination giving excellent image resolution and depth. A colour image requires red, green and blue filtered exposures, but I also like to add hydrogen-alpha (Ha) data to enhance the structures of faint nebulae. The bushfires that engulfed much of southeastern Australia at the time had a significant effect on my attempts to capture any image data. Time after time, smoke from these fires made imaging impossible, shrouding not just my small observatory, but also thousands of square kilometres around it; indeed, NASA satellite data later showed the aerosols completed an entire circuit of Earth.

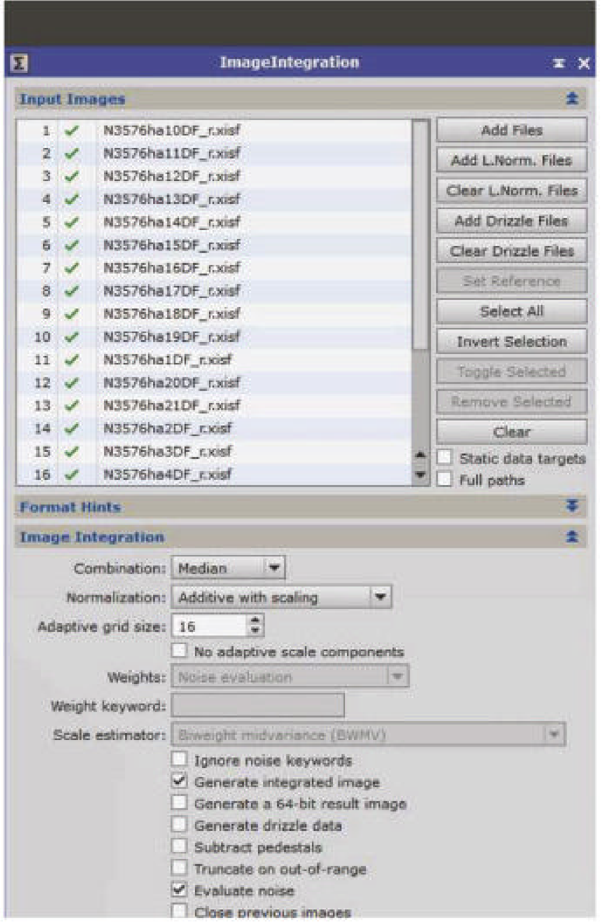
With attempts to capture colour data thwarted, my attention was focused on the four hours of Ha exposures I had managed to acquire. Mid-evening news reports of the fires showed vast arcing and turbulent fireballs – structures that were uncannily similar to my Ha data. In this article I will explain my workflow and how my 'Cosmic Inferno' took shape.

To begin, I calibrated the RAW image

ALL PICTURES: PETER WARD




▲ **Screenshot 1: The PixInsight 'StarAlignment' window is used for registering the images...**



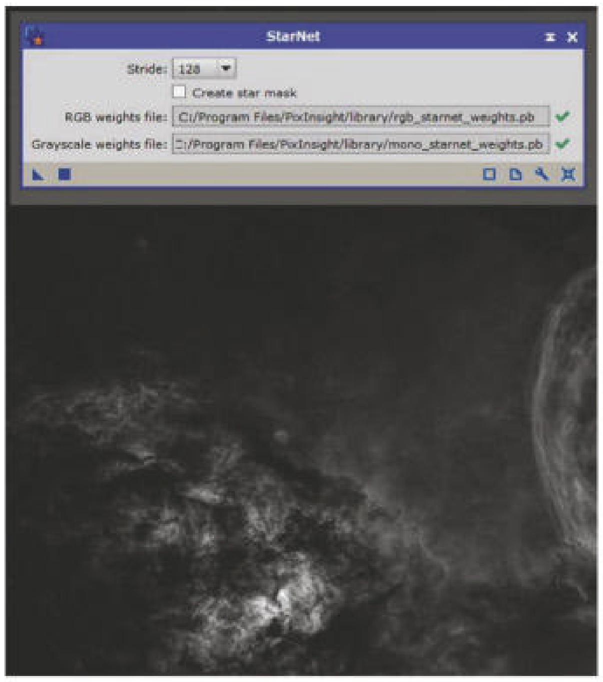

▲ **Screenshot 2: ...and the 'ImageIntegration' window is then used for stacking the images**

# 3 QUICK TIPS

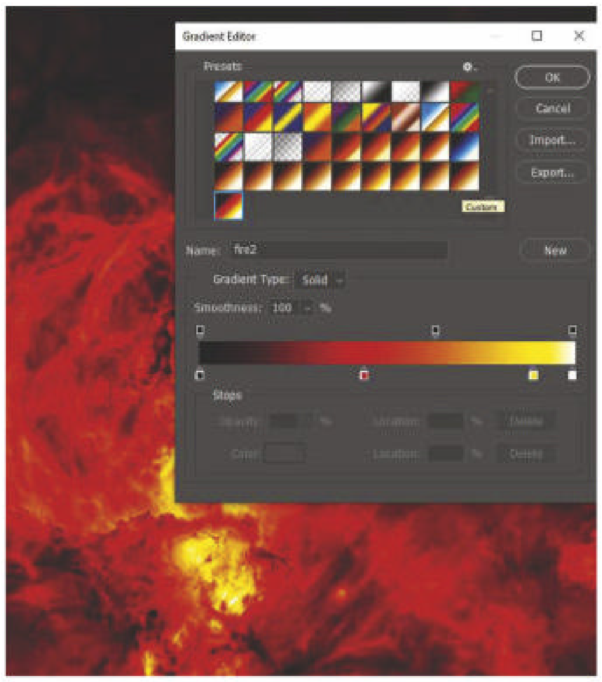
**1.** Respect the GIGO principle (garbage in, garbage out), and don't waste time by trying to recover detail from poor quality data.

**2.** Always calibrate your RAW image data; without flats and darks your data will be inaccurate and noisy.

**3.** Don't be afraid to push the processing envelope, but always respect the intrinsic illumination of an object.




▲ **Screenshot 3: Use the 'StarNet' function to remove unwanted stars**




▲ **Screenshot 4: A colour palette is applied to the grayscale image in Photoshop**

files (see top right image on the opposite page) with suitably matched dark and flat frames; this essential step removes thermal noise (unwanted artefacts), vignetting and the shadows from any dust motes. For image registration and stacking I use PixInsight software because of its sub-pixel registration accuracy and noise-reducing algorithms.

## Getting started

To start the registration process in PixInsight, click on 'Select › Process › ImageRegistration › StarAligment' to bring up the 'StarAlignment' window (see Screenshot 1, above) and then click 'File' in the top right drop-down option and choose a reference image. Next, click on the 'Add Files' button to add your sub-exposure files for registration, and then click on the folder icon to the right of the 'Output directory' and select a folder to store the registered images. Now, click on the 'Apply Global' icon and you're done (see Screenshot 1). Once registered, the image data needs stacking and this is done in the 'ImageIntegration' window (see Screenshot 2), which is found by clicking 'Process › ImageIntegration › ImageIntegration'.

Click the 'Add Files' button to add previously registered image data. I use the 'Median' combine setting and 'Winsorized Sigma Clipping' to reduce noise. Clicking the 'Apply Global' button stacks the images. The combined image file can now be brightness-stretched to your liking; the key is to use subtle changes to bring out shadow details without burning out the highlights. To mimic a maelstrom of swirling flames I needed to remove the stars from the image data and show just the nebulosity.

To do this I select the 'StarNet' function in PixInsight, opened by clicking 'Process › ObjectRecognition › StarNet' (see Screenshot 3). Next, I click on the square 'Apply' button, saving the resulting star-less image file for further processing.

The 'StarNet' star-removal routine is not perfect and it leaves bright star halos and diffraction spikes in the image, but these can be removed in Adobe Photoshop by using 'Patch' or 'Clone' tools, as well as applying Photoshop's noise-reduction filter ('Filter › Noise › Reduce Noise') to smooth out the nebulosity.

The last step in the process is to "colourise" the image, or map a colour palette to the grayscale image in Photoshop. A new layer can be added by selecting 'Layer' › 'New Adjustment Layer' › 'Gradient Map'. By clicking on the gradient icon, you can select and define a range of colours to map brightness changes within the selected grayscale image (see Screenshot 4). By moving the adjustment sliders you can also vary the brightness levels with different colour transitions.

Despite plenty of tinkering with my grayscale image, I found that using only shades of red gave an unconvincing result. However, I discovered there was no better colour guide than in the actual news footage images of the bushfires. By using Photoshop's colour selection tool, I sampled the purple-black, red, yellow and orange tones from these images and placed them into the gradient of the adjustment layer. The final result was perfect (see main picture, opposite), and gave something of an Earthly relevance to the vast cosmic structures far beyond our home planet.

**Peter Ward** lives in Sydney, Australia. He was the winner of the APY 2020 'Stars and Nebulae' category with 'Cosmic Inferno'

Your best photos submitted to the magazine this month

# ASTROPHOTOGRAPHY GALLERY

**CAUTION**
Only observe and photograph the Sun with certified solar-safe equipment

More **ONLINE**
A gallery containing these and more of your images

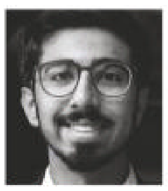
## SOLAR ECLIPSE SPECIAL

Some of our readers' best images of the partial solar eclipse on 10 June 2021

PHOTO OF THE MONTH

### △ Rising over Lake Michigan

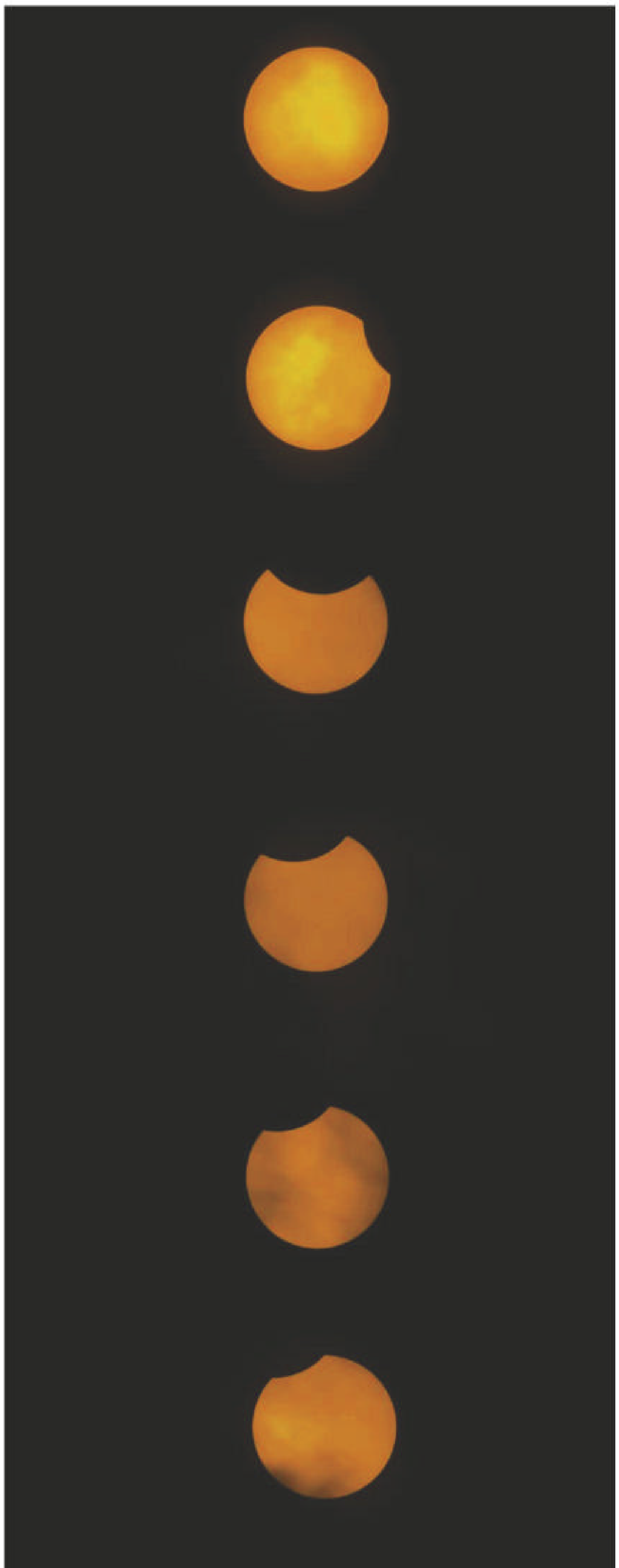
**Chirag Bachani, Evanston, Illinois**



**Chirag says:** "After months of planning and waking up early to practise sunrise shots, my friend Jesus Hernandez and I watched in awe as the crescent Sun rose over the water's edge. As the Sun crept higher in the sky, I dimmed my exposure and captured this image of the Sun's bottom edge lifting off Lake Michigan."

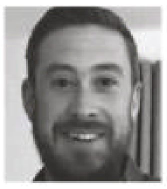
**Equipment:** Olympus OM-D EM10 II mirrorless camera, Olympus M.Zuiko Digital ED 75–300mm lens **Exposure:** ISO 1000 f/6.7, 1/800" **Software:** Lightroom

**Chirag's top tips:** "The most important part of capturing a solar eclipse is preparation. Use an app such as PhotoPills to determine the location and timing of the eclipse. Go on location several days in advance and practise taking images of the Sun. Experiment with focal lengths and include various foreground elements to make your images interesting. Keep the shutter speed fast and the aperture high to create the sharpest Sun images. Adjusting the camera settings in advance allows you to enjoy the moment while focusing on capturing the perfect image."



## ◁ Solar sequence

**Dan Fleetwood, Rugby, Warwickshire**

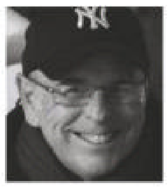


**Dan says:** "I had cloud breaks across the two hours of the eclipse. I put this sequence together to show the phases."

**Equipment:** Canon 600D DSLR, Sky-Watcher Evostar 72ED apo refractor, Sun Catcher filter, Star Adventurer mount **Exposure:** ISO 100, 1/160" **Software:** Lightroom, Photoshop

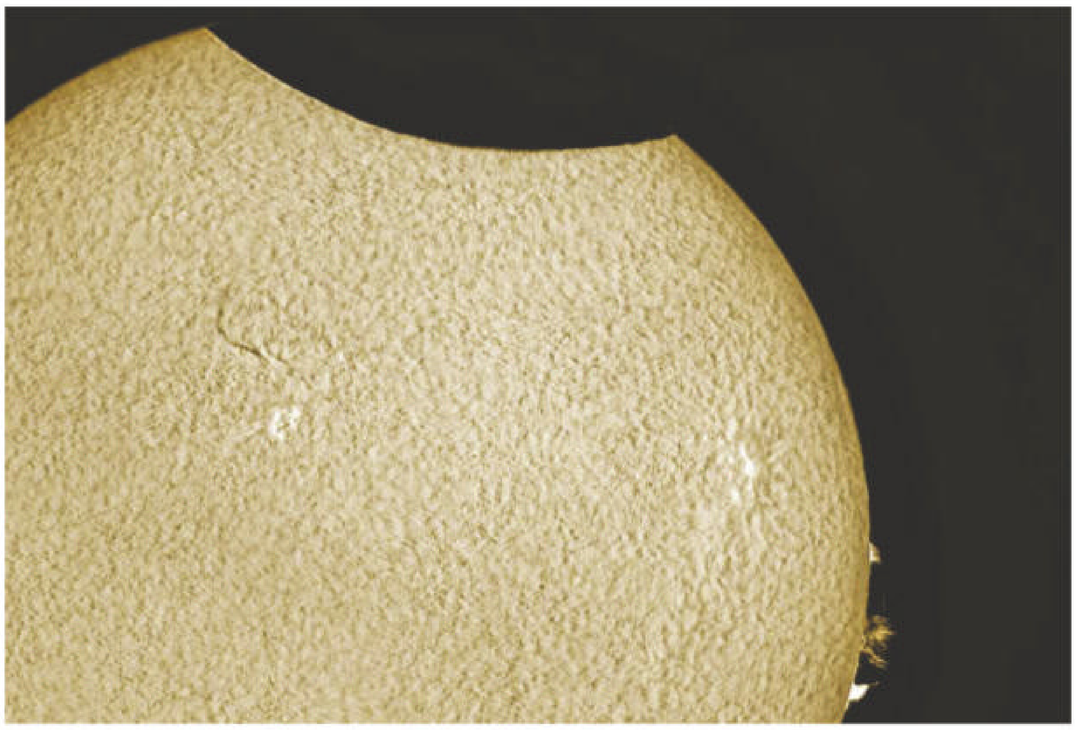
## △ Angel of the North

**Simon Woodley, Gateshead**



**Simon says:** "I wanted more than just the Sun and Moon; it was hard managing the exposure of the Sun and the statue, but I like this shot."

**Equipment:** Canon R6 mirrorless camera, Canon RF 24–240mm lens, graduated filter **Exposure:** ISO 100, f/11, 1/8000" **Software:** Lightroom

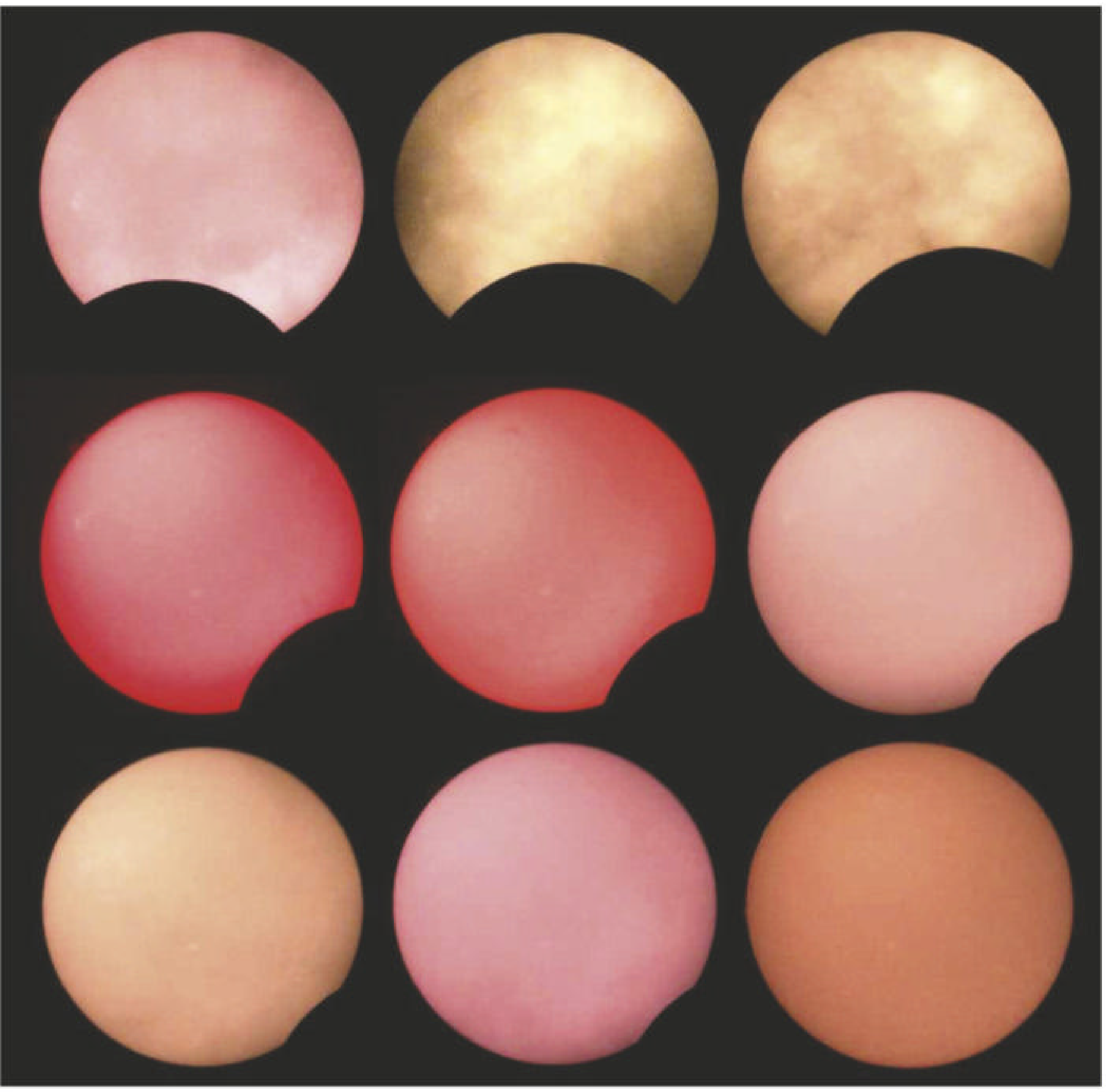


## △ Eclipse and prominences

**James Robertson, London**

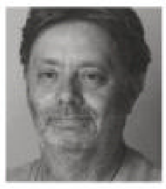
**James says:** "I captured the eclipsing disc in a short-lived blue patch in the gloom over south London, then combined this with prominences that I'd caught earlier that morning."

**Equipment:** ZWO ASI178 mono camera, Lunt LS60THa H-Alpha solar telescope, Sky-Watcher SolarQuest mount **Exposure:** 2.4ms (surface), 42ms (prominences), gain 50 **Software:** AutoStakkert!, Photoshop



## △ Screen time

**Stuart Atkinson and Stella Coxon, Aviemore**



**Stuart says:** "All the weather forecasts had laughed at us, but on the morning we had great views. We also used our Celestron NexStar 130SLT to project the Sun's image on to a white screen."

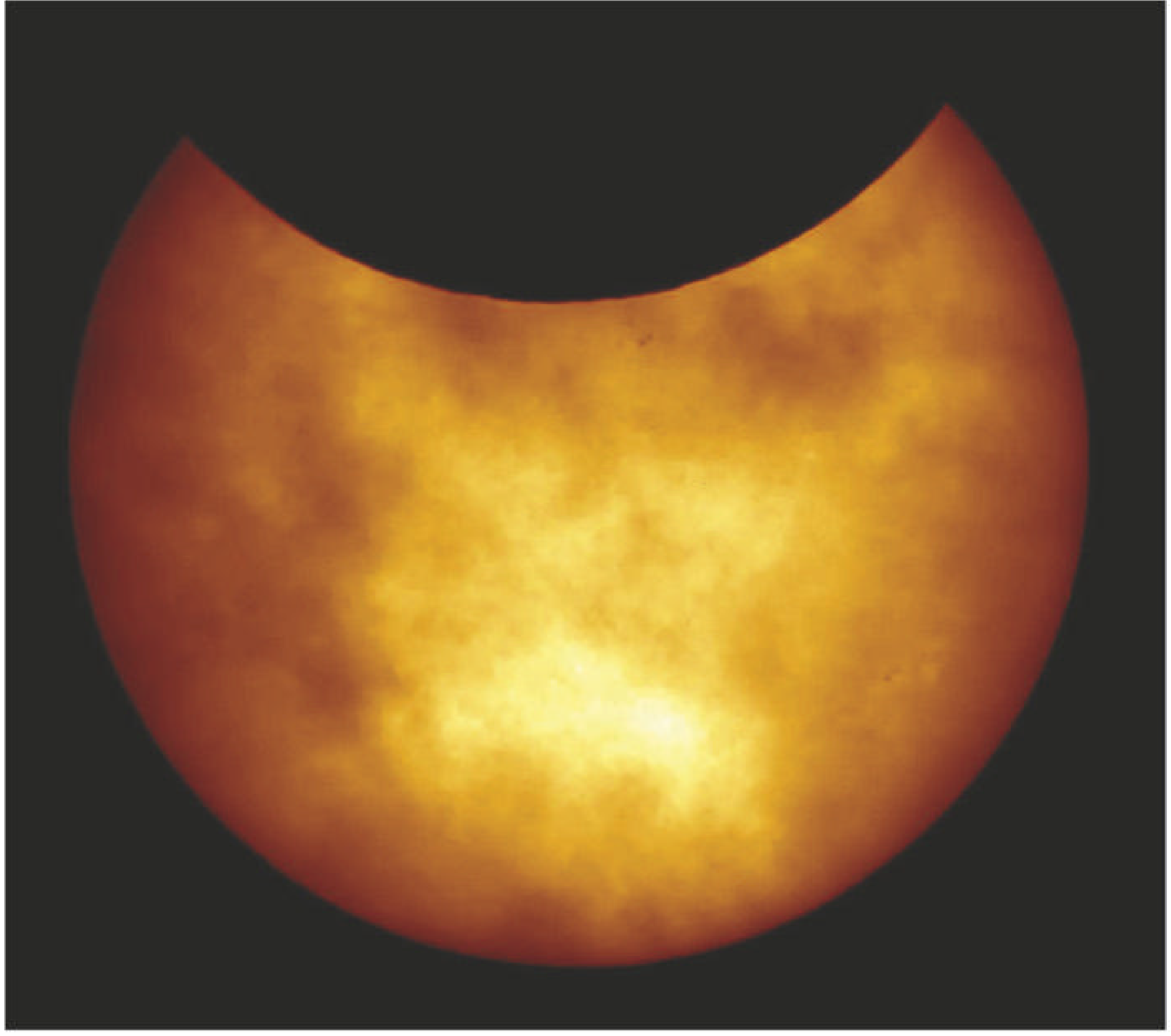
**Equipment:** Canon 700D DSLR **Exposure:** ISO 200, f/45, 1/3200" **Software:** FastStone

## ◁ Pastel phases

**Alex Sultoon, London**

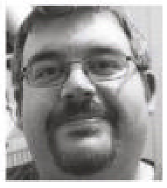
**Alex says:** "Compared with the transits of Venus in 2012, Mercury in 2016 and 2019, and the eclipse in 2015, this partial eclipse was relatively cloud free! I was able to record far more than before, which gave me the idea of creating this composite."

**Equipment:** Bresser HD WiFi camera, Coronado Personal Solar Telescope, Manfrotto tripod **Exposure:** (individual frames taken from video) **Software:** Affinity Photo



## ◁ Break in the clouds

**Mark Forbes, Woodley, Stockport**

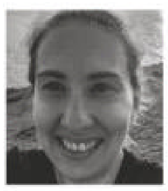


**Mark says:** "This was not long after maximum coverage here in the northwest of England. The heavy clouds were a hindrance, but the contrast with the bright Sun created a dramatic scene. Some small details such as sunspot group AR2832 were even visible."

**Equipment:** Altair Hypercam IMX174 mono camera, Altair Starwave 102ED refractor, Baader 10nm Solar Continuum filter, Sky-Watcher AZ-EQ6 GT mount
**Exposure:** 15.000ms, gain 113
**Software:** SharpCap, Photoshop

## Mobile magic ▷

**Sonia Turkington, Reddish, Stockport**

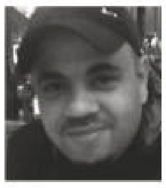


**Sonia says:** "I used my mobile phone handheld (afocally) to the eyepiece. I was so happy to see this eclipse, having waited patiently all morning to get a brief 20-minute clear spell."

**Equipment:** Google Pixel 4 mobile phone, Sky-Watcher 10-inch Skyliner 250PX Dobsonian fitted with a Seymour thin film solar sheet

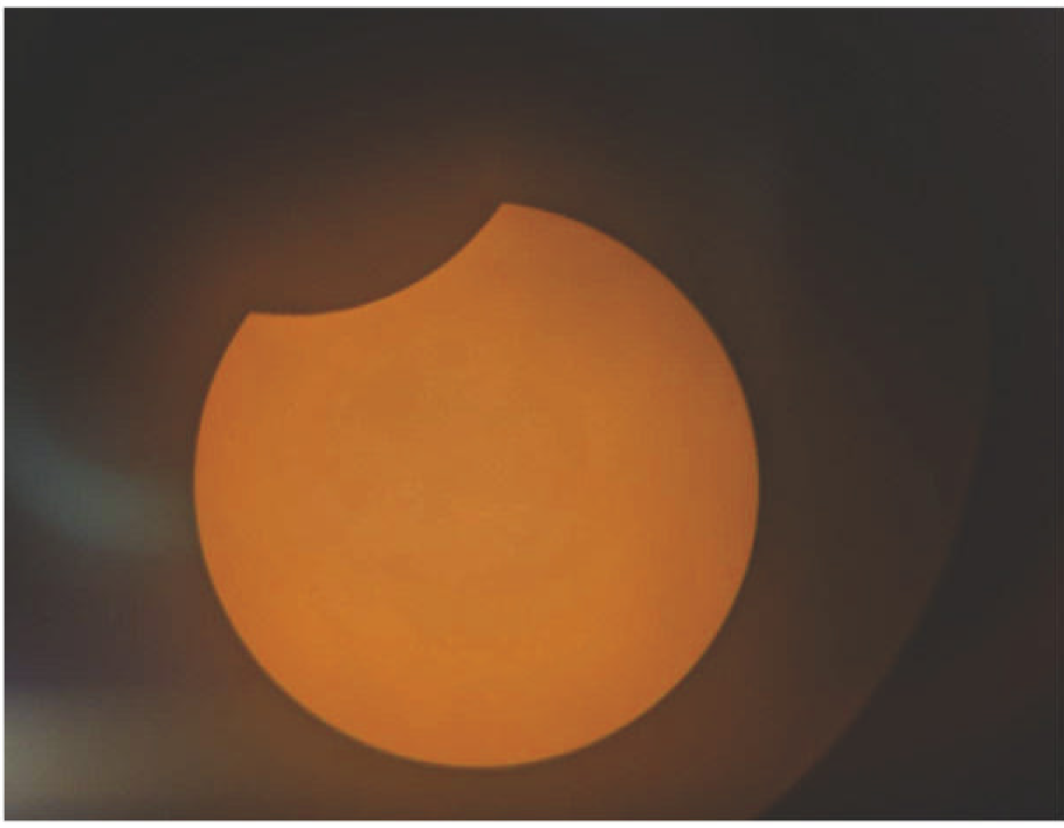
## ◁ Purple haze

**Nick Dunbar, London**



**Nick says:** "This was taken from the Chelsea Embankment, not far from my work. It was my first time imaging an eclipse and using a lens filter, so I was very happy with the result."

**Equipment:** Canon 200D DSLR, Canon 55–250mm lens, neutral density filter **Exposure:** ISO 400 f/32, 1/500"
**Software:** Apple Photo app



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**The StarSense Explorer DX 6 Schmidt-Cassegrain telescope allows control via its handy smartphone app. We see how the setup measures up**


## HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

**PLUS: Books on particle physics and the life of NASA's Katherine Johnson, plus the latest must-have astronomy gear**

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# Celestron StarSense Explorer DX 6-inch Schmidt-Cassegrain

An app-enabled telescope, which allows your smartphone to dock and guide it

WORDS: PAUL MONEY

**VITAL STATS**

- **Price** £699
- **Optical design** Schmidt-Cassegrain
- **Optics** 150mm
- **Focal length** 1,500mm, f/10
- **Mount** Manual altaz mount with slow-motion controls
- **App control** StarSense Explorer app with StarSense Sky Recognition Technology and planetarium
- **Extras** StarSense dock for your smartphone, 40mm and 10mm eyepieces, star diagonal, StarPointer red dot finderscope
- **Weight** 6.35kg
- **Supplier** Celestron
- **Tel** 0118 467 1200
- **www.**celestron.com

Do you fancy having Go-To functionality without the hassle of motorised drives and a complex equatorial or altaz mount that costs a fortune? Well, this is where Celestron's StarSense range comes into its own. By employing a clever app on your smartphone, combined with a carefully designed adaptor to hold it, the StarSense series does just that. As the StarSense Explorer DX 6-inch Schmidt-Cassegrain is currently the largest and latest offering in the series, we were keen to try it out.

The StarSense Explorer DX 6 is a 6-inch (150mm) Schmidt-Cassegrain telescope, which uses a primary mirror at the rear, and a corrector plate and secondary mirror at the front to fold the light path into a short tube. It has a focal length of 1,500mm, giving a focal ratio of f/10, and the tube is only 406mm long making it quite compact. It is mounted on a basic yet effective manual 'Push-To' altaz mount; while slow-motion controls allow you to make fine-tuning adjustments to the position of the telescope, it can also be moved by hand for rough alignment. The mount also houses the smartphone adaptor/phone dock; when you are using the downloadable StarSense Explorer app (see box, below) this enables you to align your smartphone with where the telescope is pointing.

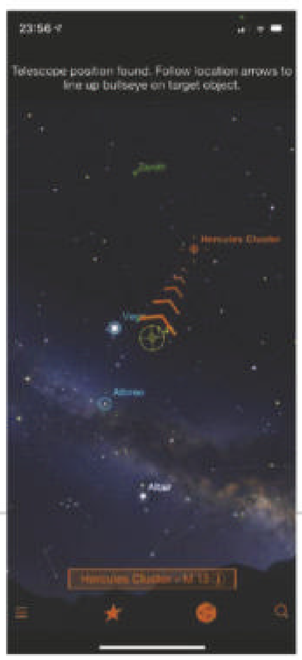
## Added benefits

The accompanying black aluminium tripod has ample leg adjustment to put the telescope at a convenient height to use with a basic yet effective spreader accessory tray. The StarSense Explorer DX 6 is supplied with two eyepieces, 40mm and 10mm, which give magnifications of 38x and 150x respectively, ▸

## Admirable app and adaptor

The StarSense adaptor/phone dock lies on the other side of the mounting arm to the telescope, and this lines up perfectly with the direction the telescope is pointing. Simply download the StarSense Explorer app from Google Play or the Apple app store and insert your smartphone in the holder. When the app starts up you can align the smartphone with the telescope, which is best done in the daytime on a distant target for accurate alignment. The adaptor positions your smartphone over a mirror, allowing its camera to 'see' the night sky.

The app is very effective and is at the core of the StarSense system; it plate-solves the view of the sky the phone camera sees and works out where it is pointing. This allows the planetarium aspect of the app to show you the way via onscreen arrows to a target (below, right). Move the scope manually until you are almost on target, leave the scope to refine its position, then you can fine tune the position so the indicator box turns green when you're on target. There is also a red light night mode (below, left).



@THESHED/PHOTOSTUDIO X 3, PAUL MONEY

SCALE

## Optics

The StarSense Explorer DX 6 optics comprise a 150mm-diameter mirror and front corrector lens with a focal length of 1,500mm, giving a focal ratio of f/10. The corrector lens is multi-coated to improve light transmission for brighter, crisper views of a wide variety of targets, from the Moon to the deep sky.

## Optical tube

The optics are housed in an aluminium tube measuring 406mm in length and 184mm in diameter, while the whole optical tube assembly weighs only 4.54kg, making it relatively light, portable and easy to attach to the mount. It has a stylish silver and black finish.


## Accessories

Two 1.25-inch eyepieces of 40mm and 10mm are provided, giving magnifications of 38x and 150x, along with an erect-image star diagonal that is useful in an altaz system. A StarPointer red dot finder is also provided and this helps with initial alignment, after which you can use the StarSense Explorer app.

## Tripod

The black, aluminium tripod is light, weighing just 1.72kg, and extends to a maximum height of 1.32m, which gives a good range of adjustment. It comes with a simple but useful accessories tray that can take the eyepieces and other accessories, keeping them handy for use.

# FIRST LIGHT

**KIT TO ADD**

**1.** Celestron PowerTank Glow 5000

**2.** Celestron Omni 2x Barlow lens, 1.25-inch

**3.** Celestron Moon filter, 1.25-inch

▸ while an erect image star diagonal and simple red dot finder complete the setup.

Unlike the refractor models in the StarSense range, the Explorer DX 6 mount has the smartphone adaptor placed on the other side of the support arm to the telescope, so it moves in sync with the scope when you adjust the altitude.

With our iPhone XR docked and using the StarSense Explorer app, we first had to perform a simple, one-off alignment procedure during daytime to ensure the phone's camera was lined up and looking at the mirror on the adaptor. This is key to ensuring the planetarium aspect of the app can plate-solve the night sky and provide accurate target locations and aiming directions. Once activated, you just keep the telescope pointing at a part of the night sky that is unobstructed and it determines where it is pointing. Next, you can either tap a target on the displayed sky map or go into the menu and select a target from a suitable list, following the on-screen prompts to move the scope to it.

## Taking in the sights

We took a tour of the galaxies of M81 and M82, which fit nicely in the field of view of the 40mm eyepiece. Switching to the 10mm eyepiece, M82 appeared as a broken sliver of light, while M81 was an oval glow. In the north we located the Double Cluster, which was nicely framed in the 40mm eyepiece with a sprinkling of orange stars between its two open clusters. Nearby was a favourite open cluster, M103, which lost none of its splendour in the 10mm eyepiece. Indeed, the 10mm came into its own on double and multiple stars as we took in the coloured double of Albireo (Beta (β) Cygni), with its golden yellow primary and sky-blue companion. The triple star Iota (ι) Cassiopeiae could just be resolved and the 'double-double' star of Epsilon (ε) Lyrae had both sets of stars split cleanly with the 10mm.

The Dumbbell Nebula, M27, was impressive with the 40mm eyepiece, while the Ring Nebula, M57, showed a dark centre with the 10mm. Although we had no planets on view due to local horizon obstructions, we were rewarded with plenty of detail on the Moon. It is worth noting that the StarSense Explorer app only works at night when it can plate-solve using the stars, but you can use its star pointer finder to line up on obvious targets such as the Moon in the daytime.

Overall, we found the StarSense Explorer DX 6 proved to be an enjoyable experience to use.

## Mount

The mount is a single-arm altaz design allowing manual movement up, down and side to side. There are two slow-motion controls for fine-tuning the altitude and azimuth position. Rough positional adjustment is done by manually pushing the system by hand. The telescope is attached via a Vixen-style CG5 bar.



# VERDICT

| | |
|---|---|
| **Assembly** | ★★★★★ |
| **Build & design** | ★★★★★ |
| **Ease of use** | ★★★★★ |
| **Features** | ★★★★½ |
| **Optics** | ★★★★½ |
| **OVERALL** | ★★★★★ |


# Serif Affinity Photo image-processing software

A user-friendly astrophotography program with updated adjustment tools

WORDS: DAVE EAGLE

**VITAL STATS**

- **Price** £48.99
- **Core program** Photo editing and processing
- **Features** Astro imaging 'Personas' (for desktop only), combining RGB images, background removal tool, star alignment tool, star reduction tool and 'Astro photography Stacking Persona'
- **Updates** Free, until a major update is released
- **System** Windows 7 SP1, 8.1 & 10, Apple Mac 10.9 and up and iPad iOS 12 and above
- **Requirements** 2GB RAM, 1280 x 768 display or better for desktop
- **Developer** Serif
- **Email** affinity@serif.com
- **https://affinity.serif.com/en-gb/photo/**

Affinity Photo is the image-processing package in Serif's Affinity suite of products, gaining popularity with many professional photographers who are discovering just how powerful the software is. The program is constantly being updated, with some extremely useful astrophotography tools being introduced earlier this year. The most notable are tools for star alignment, and background and gradient removal, as well as Affinity's 'Astrophotography Stack Persona'. Here, we take a look at these and other features that are useful for astrophoto processing.

These new astrophotography tools will certainly turn the heads of many astro imagers who are wanting a single package that does everything at an affordable price. We particularly liked Affinity Photo's single one-off payment user licence model, as it means you're not locked into making long-term monthly payments. The only time the licence holder will be asked for extra payments for the software is when Serif releases a major software update with new features. Unlike a lot of software, the licence allows the software to be installed on as many machines as you have, running on either Windows or Apple operating systems, plus there is a cheaper iPad version. You'll need a separate licence to run the software on the different platforms.

The installation files proved easy to download and they were installed flawlessly on the Windows and Apple computers we tried. New updates were prompted, downloaded, ▸

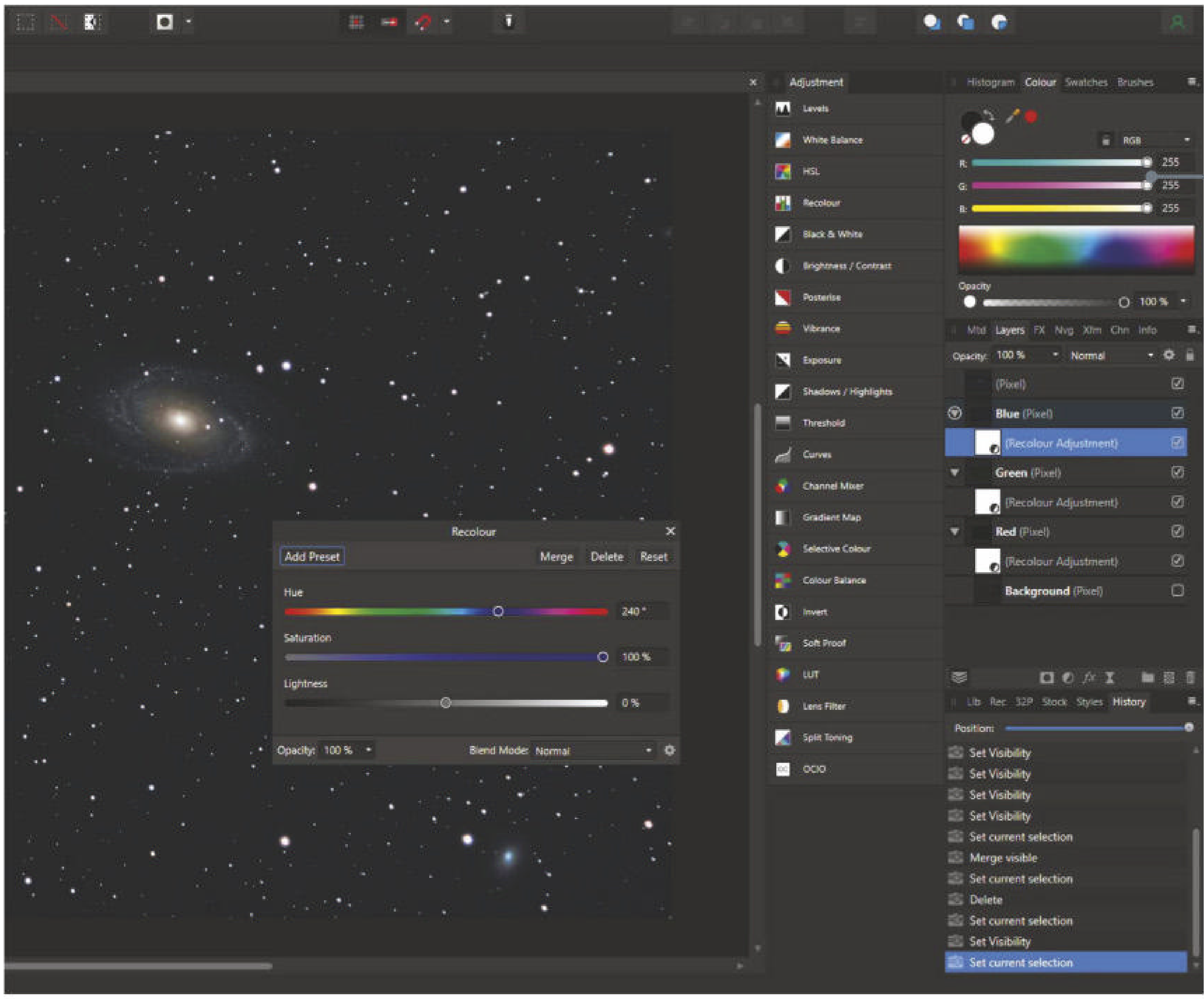
## Streamlined stacking

One-shot colour, monochrome RAW and FITS camera images can be stacked using Affinity Photo. Calibration frames such as bias, dark, dark flats and flat frames can be included to help improve the results. Different stacking methods can be used, depending on the results you require, or the data you have. There is also the ability to select different types of mono or colour Bayer patterns, depending on your camera. The images we stacked from both one-shot colour DSLR and monochrome astronomy camera sub-exposures were superb. These displayed great contrast and colour, and fine definition once processed within Affinity's 'Photo Persona'.

By adding dark frames, we removed the normal amp glow visible in the sub-exposures from our mono camera. A slight niggle is that there is no comet stacking setting and if this could be included in a later edition, it would be a most welcome feature.

The 'Astrophotography Stack Persona' (below) opens the door to opening and editing single FITS files from within the software, which is something that cannot be done with most other up-to-date versions of photo-processing software.

ALL PICTURES: DAVE EAGLE/AFFINITY PHOTO




## Combining RGB images

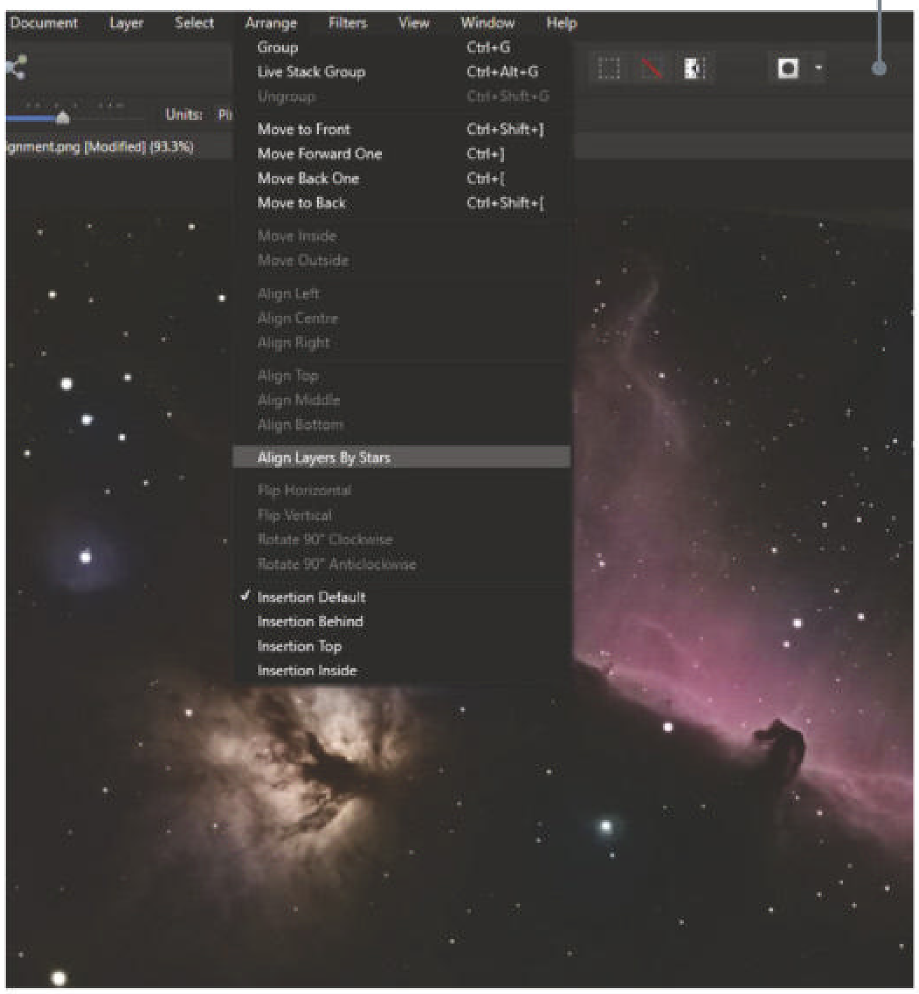
Combining RGB (Red, Green and Blue) images is a little bit more involved than it is in other image-processing packages, but there is an easy way to use layers and the 'Recolour' tool to create LRGB (Luminance, Red, Green and Blue) and Hubble Palette images from mono images taken through different filters.

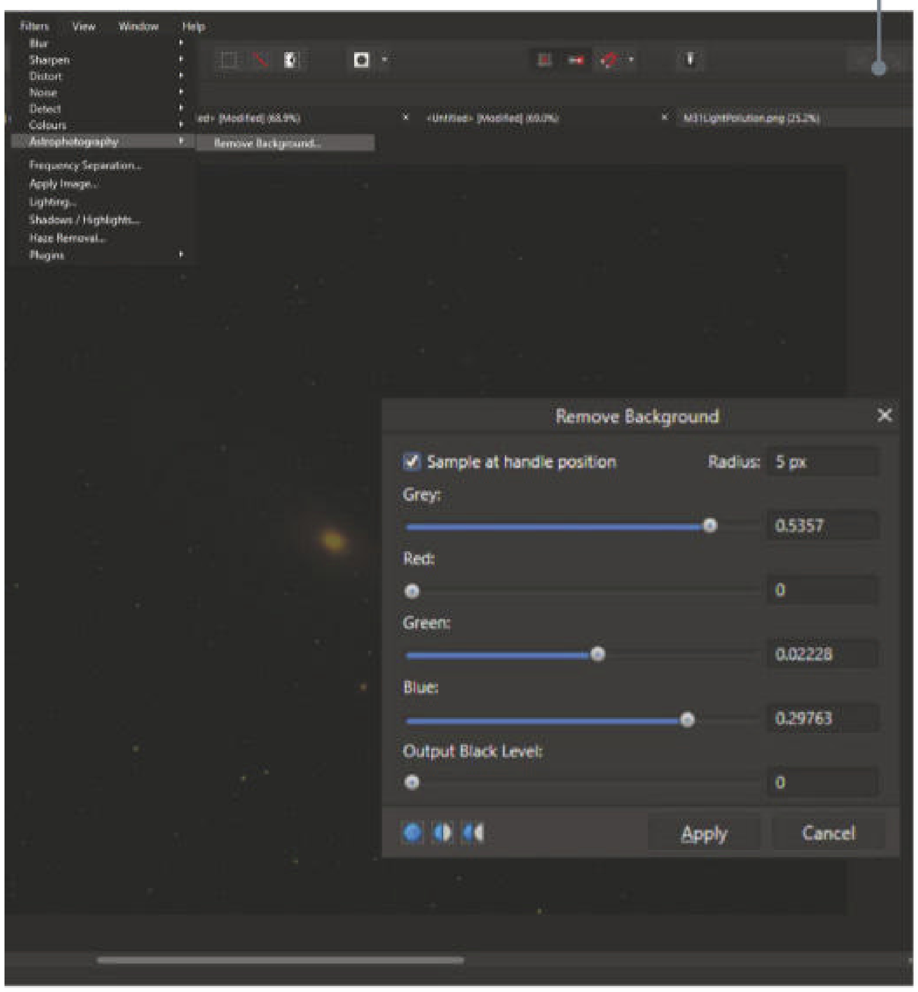
## Star alignment tool

The 'Align Layers by Stars' tool aligns two images by analysing the positions of stars in each layer. We used it to add old colour DSLR data onto a high-resolution mono image. It handled good-quality images extremely well, but struggled to align some lower-quality images we used for testing.

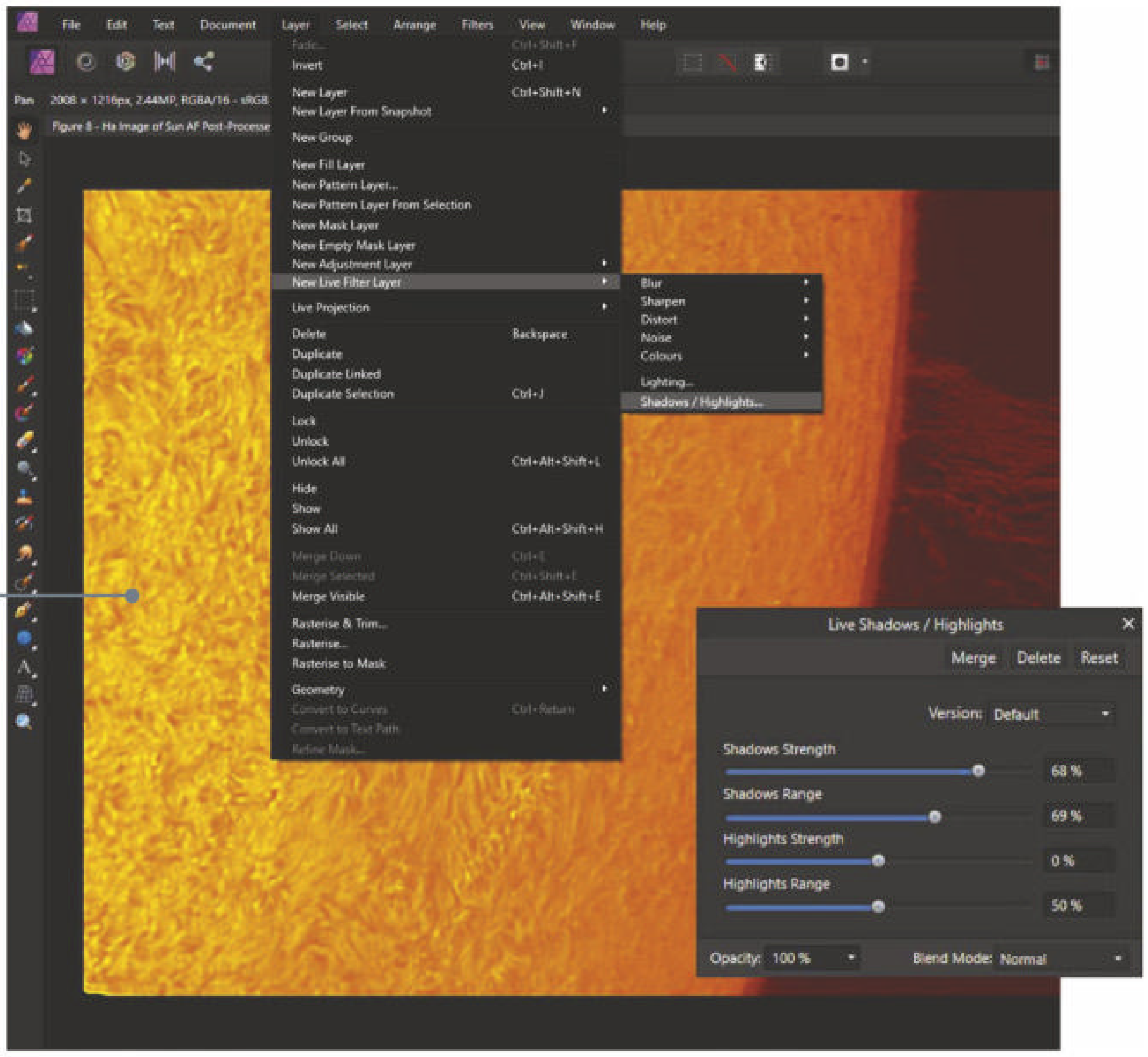
## Background removal tool

The 'Remove Background' tool removed both bright backgrounds and gradients from our stacked images. You simply add single or multiple handles for gradients onto the image. In our image of the Andromeda Galaxy the background was removed, enabling us to tease out more detail later.



# FIRST LIGHT




## Planetary, lunar and solar image processing

**Affinity Photo has some great sharpening tools and low light level handling tools. The software can also be used to process planetary, lunar and solar images. We used these to help tease out fine and faint detail, enhancing colour on the planets and the lunar surface, and revealing faint prominences in hydrogen-alpha solar images.**

▸ and installed without issue. Four icons located at the top left, just below the menu bar, are the gateways to what Serif calls Affinity's 'Personas', each of which changes the software to a particular role. We only needed to use two of these in our testing; one is the 'Photo Persona', where you make all the edits and adjustments to your images. The other is the 'Develop Persona', which is opened automatically when RAW camera image files are opened. Adjustments can be made from here, before opening within the 'Photo Persona' for further editing. For this review we didn't need to use the other three options: 'Liquify', 'Tone Mapping' and 'Export'.

## Easy to use

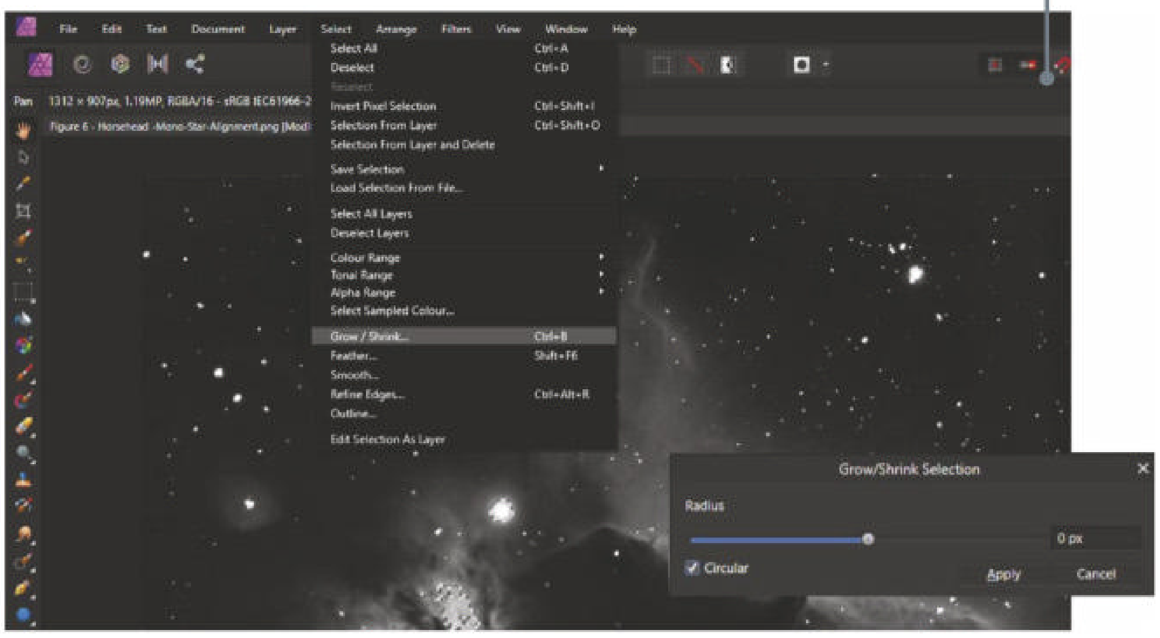
The user interface is similar to most image-processing software and is easy to use, with a menu bar at the top, a tool bar down the left and lots of tabs to access different 'Adjustment' tools, including 'Curves', 'Levels' and so on. We liked the way that the interface layout can be managed. Tools can be switched on and off and their position on the screen can be changed to make it easier for the user to set up for their own convenience. But we found that the 'Adjustment' tools do not allow you to re-arrange them, neither are they arranged alphabetically. So it can take a bit of getting used to finding the 'Adjustment' tool you want, but this is a minor niggle.

The 'Adjustment' tools work nicely, creating an adjustment layer above the image layer being worked on. These can be manipulated, moved about and even nestled within other layers. We did have an issue when saving TIFF files – these are saved as compressed files by default, which can cause problems if being used in other software. However, this default can be turned off.

Unlike Adobe Photoshop, Affinity Photo cannot use 'Actions' to carry out repetitive processing tasks by using just a single mouse click, but you can create macros and save many pre-set 'Adjustment' tool manipulations to do the same thing. Some Photoshop plug-ins can also be installed and used within Affinity Photo, which is a useful feature if you already own these.

## Star reduction setting

**Stacked and processed images often result in bloated stars. Although not a specific tool, the 'Grow/Shrink Selection' setting helps to reduce the size of foreground stars on deep-sky objects. This helps the feature of interest, such as a nebula or galaxy, to stand out and become much more prominent.**




Overall, we found that Affinity Photo is a well thought out and extremely powerful product. The latest version with the new image-stacking and astrophotography tools makes it the ideal package for an astro imager. If you've already used image-processing software, the transfer should be reasonably straightforward. What's more, all this is available at a great price.

## VERDICT

| | |
|---|---|
| **Ease of use** | ★★★★☆ |
| **Extras** | ★★★★☆ |
| **Features** | ★★★★☆ |
| **Functionality** | ★★★★★ |
| **Installation** | ★★★★★ |
| **OVERALL** | ★★★★½ |

### KIT TO ADD

**1.** Astro photography imaging kit

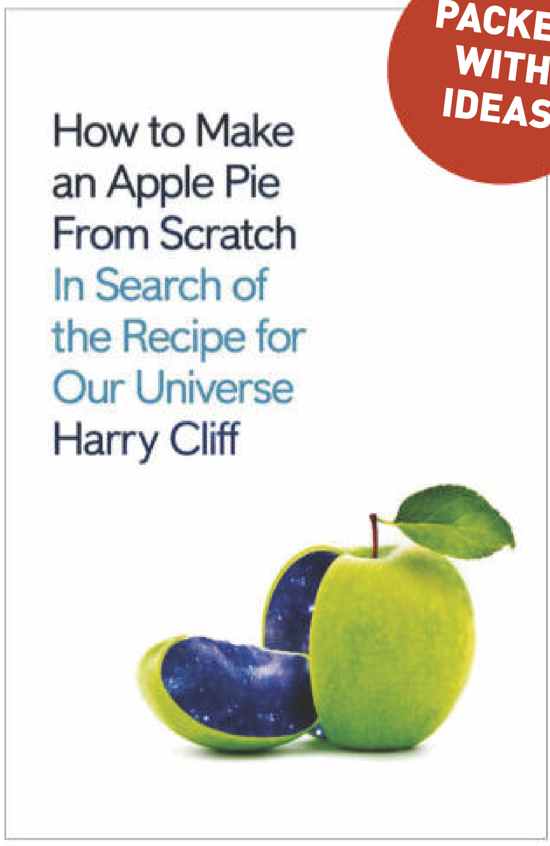
**2.** Powerful PC/Mac or laptop suited to graphics processing

**3.** Photo quality inkjet printer

ALL PICTURES: DAVE EAGLE/AFFINITY PHOTO

# BOOKS

PACKED WITH IDEAS




## How to Make an Apple Pie from Scratch

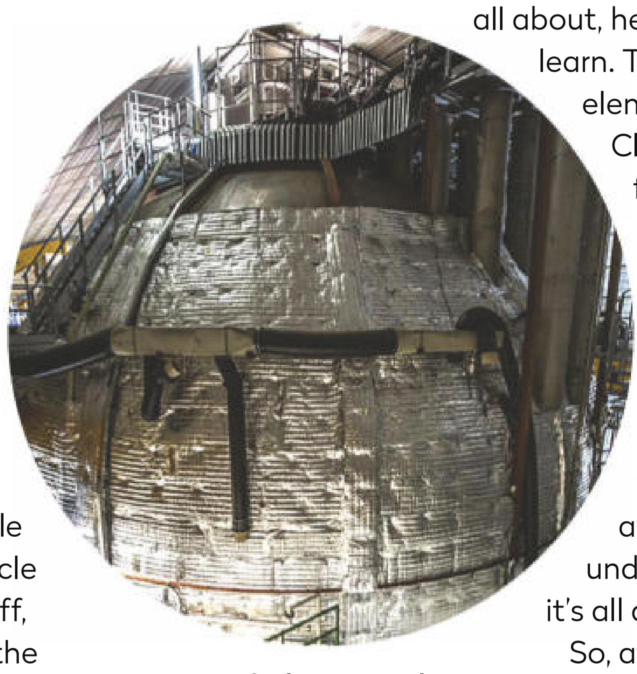
**Harry Cliff**
**Picador**
**£20 ● HB**

Unless you're a big fan of the late astronomer Carl Sagan, you might be at first puzzled about whether the title of this book, by particle physicist Dr Harry Cliff, actually belongs on the same shelf as other popular physics books. I would say, however, that this is one of the best books of that genre I have read.

Starting with an apple pie, Cliff works backwards, breaking down the ingredients to their elements, then atoms, and keeps on going to describe what we believe is happening on the smallest of scales. This book is a wonderful exploration into the origins of matter – and how you got to be here reading these words.

What sets this book apart are the human stories that are woven into the physics being described. Of course you'll read about the giants of particle physics, but Cliff also introduces a new generation of scientists who are pushing the boundaries of our understanding. You'll be connected to the experiments these ordinary scientists are working on, and share in their passion. My favourite examples include the DeLorean-like machine under London's streets that is looking for undiscovered quantum fields, or the Borexino experiment below an Italian mountain that is studying solar neutrinos.

The storytelling is really captivating and easy to follow. This book soon replaced my usual bedtime reading: something a popular physics book has never done. I will, however, admit that the last third of the book gets heavy. If you've heard the terms 'quantum field theory', 'supersymmetry', or the 'Higgs field' and wondered what it was all about, here is where you'll learn. This is another great element of the book. Cliff stares right in the face of some of the most bizarre physics concepts we have. Instead of brushing over quantum electrodynamics, for instance, you will instead come away with a good understanding of what it's all about.



**Deep below an Italian mountain, Gran Sasso, the Borexino detector is on the look out for solar neutrinos**

BOREXINO COLLABORATION

So, at the end of the book you may be able to 'invent the Universe': take the ingredients, which include a smidge of spacetime, and follow the witty instructions that detail how to actually make an apple pie from scratch. ★★★★★

***Laura Nuttall** is a Reader of Astrophysics at the Institute of Cosmology and Gravitation at the University of Portsmouth*

## Interview with the author
## Dr Harry Cliff

**What is particle physics?**

It's where you get if you keep asking 'why?'. It describes how the Universe works deep down. What is the world made of? What are the ingredients and how do they behave, how do they interact? It started 100 or so years ago when we realised there was a substructure within what we thought of as the most basic building blocks of matter. Since the discovery of the electron we've discovered dozens and dozens and dozens of [subatomic] particles.

**Do we understand why anything exists?**

We can tell a lot of the story. You can break an apple pie down to chemical elements and trace their origins through the Universe's history. Everything, including apple pies, contains hydrogen, carbon, oxygen, the chemical elements across the periodic table. We have a pretty complete description of where these come from, forged inside stars or in the first minutes after the Big Bang. We can tell this story back to about a trillionth of a second after the Big Bang, but it's less clear beyond that.

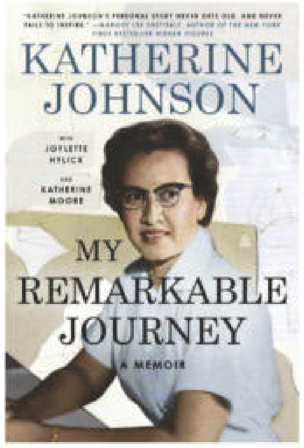
**What does the Large Hadron Collider do?**

What it does is simple and pretty brutal: it accelerates particles to high energies and smashes them into each other. It does that 40 million times a second, 24 hours a day, seven days a week for nine months of the year. When two protons collide, they have a lot of kinetic energy and that is turned into new matter. You are making particles from energy, and you might make a Higgs boson, for example. That is how these particles were discovered.

***Dr Harry Cliff** is a particle physicist at the University of Cambridge working on the Large Hadron Collider beauty experiment*

# My Remarkable Journey: A Memoir

**Katherine Johnson, Joylette Hylick, Katherine Moore**
Harper Collins
£20 ● HB




If you have seen the 2016 movie *Hidden Figures*, about the group of African-American women who worked as 'human computers' for NASA during the era of the Space Race, then you already know about Katherine Johnson. This book is her story, in her own words.

Born in rural West Virginia at the end of World War One in 1918, she died in 2020 at the age of 101. Her life spanned the Great Depression, World War Two, the Civil Rights movement, the Space Race and beyond. She was awarded the Presidential Medal of Freedom by President Barack Obama in 2015 and was given a standing ovation at the 89th Academy Awards in 2017.

Education was of paramount importance and her parents made sure she and her siblings received the best possible. A talented mathematician from childhood, she entered college at just 15.

The chapters dedicated to her work at NASA through the Mercury, Gemini and Apollo missions are fascinating and detailed. Her work put the first Americans in space, and even when the first electronic computers were introduced at NASA she had to double check their calculations.

Throughout the book Katherine Johnson is at pains to pay homage to her teachers and mentors, to her colleagues, friends and family and to those who broke through the barriers alongside her.

Her life was one of hard work, integrity, decency and dedication. It is indeed an inspiring story of a life well lived. ★★★★☆

***Jenny Winder** is a space writer and broadcaster*

# Space Exploration

**Dhara Patel**
Royal Observatory Greenwich
£9.99 ● PB


*Space Exploration* is a beautiful little book, furnishing its reader with a comprehensive overview of our millennia-old love affair with the cosmos. Penned by Royal Observatory Greenwich astronomer and educator Dhara Patel, its prose packs an appreciable punch of knowledge for its diminutive size, although conversely the narrative can often feel somewhat bland and clunky.

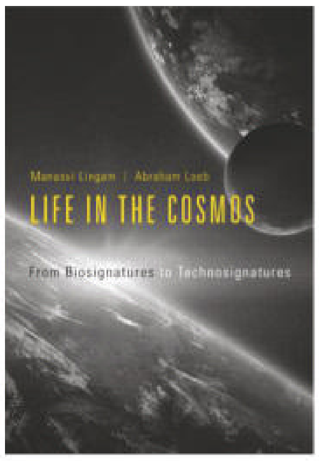
Patel traces humanity's fascination with the sky from our earliest ancestors, through religion and astrology, to the dawn of modern scientific awareness. She guides us assuredly through key issues, concepts and questions and pays due deference to the towering figures of the past who shaped our comprehension of the Universe around us. She explores the history of space travel from its dawn to the present and offers a tantalising glimpse of the future. Her background and expertise in physics is reflected in the ease with which she explains the fundamentals of telescopes and eyepieces to the lay reader.

From time to time, Patel drops unexpectedly delightful anecdotes into her tale – from a young Wernher von Braun tying fireworks to a toy car, to the eerie solitude of Apollo 11's Mike Collins in lunar orbit – but this does not always save the book from being stylistically mechanical in places. That said, *Space Exploration* does what it says on the tin: it treats its subject with the confidence and succinctness of an expert and Patel's skill provides a good introduction to the subject for amateur and professional alike. ★★★☆☆

***Ben Evans** is the author of several books on human spaceflight and is a science and astronomy writer*

# Life in the Cosmos: From Biosignatures to Technosignatures

**Manasvi Lingam, Abraham 'Avi' Loeb**
Harvard University Press
£60.95 ● HB




In the past few decades, the search for life in the Universe has moved from the somewhat niche pursuit of a few dedicated scientists to a booming area of research. The discovery of thousands of exoplanets, potentially hospitable environments on other Solar System worlds and life thriving in what had seemed to be inhospitable environments on Earth, have all played a role in bringing the science of astrobiology – the study of possible alien life in the Universe – into the mainstream.

This book from University of Florida astrobiologist Lingam and Harvard professor Loeb is a magisterial review of the current state of this fast-moving field. Across almost 900 pages (plus extensive end matter) it explores every aspect of the problem you've ever considered – and probably quite a few you haven't. After an introductory chapter discussing how we define life and the likely requirements for it to arise, the book divides neatly into three sections, looking first at the origins and evolution of life on Earth, then at the potential for life to arise in a variety of other environments (and how we might detect it) and finally at how intelligent life might give away its presence and perhaps spread across the Universe.

This is primarily an academic textbook, packed with ideas, assuming a baseline understanding of science and not afraid to deploy equations. For anyone seriously interested in the scientific possibilities of extraterrestrial life, it's the last word on the subject – for now at least. ★★★★★

***Giles Sparrow** is a science writer and a fellow of the Royal Astronomical Society*

Ezzy Pearson rounds up the latest astronomical accessories

# GEAR


## 1 Apollo flight plan poster

**Price** From £42 • **Supplier** Astrography
**https://astrography.com**

Blend science with art with this specially designed print showing the flightpath of the Apollo missions, including detailed notes of each stage. Available both as a poster and a high-quality, fade-resistant print.

## 2 NASA Solar System construction set

**Price** £14.99 • **Supplier** Firebox • **https://firebox.com**

Create your very own Solar System with this kit. Paint your own planets, mount them up and then rotate them around the light-up Sun. It's a great way to learn about the planets and it makes a unique desk toy.

## 3 Women's Charna insulated diamond quilted bodywarmer

**Price** £29.95 • **Supplier** Regatta • **www.regatta.com**

Quilted with Thermoguard insulation, this vest helps keep you warm without adding bulk so you can layer up on long, cold nights. Has two zipped pockets and back vents which can be opened up for better airflow.

## 4 Askar OIII narrowband-imaging filter 2-inch

**Price** £232 • **Supplier** 365 Astronomy
**Tel** 020 3384 5187 • **www.365astronomy.com**

**ADVANCED** Bring out detail in your deep-sky imaging with this narrowband filter, which is centred at 500.7nm to bring out OIII (oxygen) lines. The sharp cut-off at the edges of the waveband helps to lessen light-pollution effects. Available for SII (sulphur) and Ha (hydrogen-alpha).

## 5 Celestron PowerTank Glow 5000

**Price** £35 • **Supplier** WexPhotoVideo
**Tel** 01603 486413 • **www.wexphotovideo.com**

Navigate around your observing site without ruining your dark adaptation, then keep your phone or tablet charged throughout the night with this 2-in-1 torch and power pack. Charges via USB and has three brightness levels as your eyes adapt to the dark.

## 6 Orion EF Widefield 1.25-inch eyepieces

**Price** £70.99 • **Supplier** Orion
**Tel** 0800 0418 1146 • **https://uk.telescope.com**

These 'extra-flat' eyepieces are specially designed to minimise field curvature for a distortion-free view, while the wide-field view gives you an immersive observing experience. Available in focal lengths of 8mm, 12mm, 16mm, 19mm and 27mm.

Ezzy Pearson interviews Dr John Barentine

# Q&A WITH A LIGHT POLLUTION EXPERT

## Light scattering from satellites and orbital debris could be greatly increasing background light pollution, affecting astronomical observations

**Why do we want to prevent light pollution?**

What people think about first is protecting the night sky, but we have an increasing understanding of the significance of light pollution as part of the overall threat to our environment. We know that it has an effect on wildlife ecology, has a potential influence on human health, public safety and energy security – it's not simply a matter of astronomy.

**How do satellites increase light pollution?**

Until recently we weren't thinking about this issue. It came to the fore about two years ago with the first launch of the SpaceX Starlink constellation satellites; to see 60 objects at a time moving across the sky was startling. For astronomers the bright streak of a satellite running through their images cost data, but it was limited to the part of the image where the satellite actually appeared.

Our new paper takes a different view of that subject and instead asks, what is the collective contribution from all of these things in the sky? We discovered this was raising the background level of brightness in the sky by about 10 per cent. That was a startling result, and it's a lower limit because it was based on the assumption that there were only a few thousand objects in orbit around Earth. We know that over time that number will increase.

▲ **Starlink satellite trails are caught in a long exposure shot taken over London on 25 April 2020**

STEPHEN CHUNG / ALAMY STOCK PHOTO

**How much will that alter the naked-eye view?**

It is unlikely that an average observer at a very dark location will notice this effect. There are sources of light, particularly in Earth's atmosphere, that are natural in origin and are more significant contributors of light. Satellites might be contributing something like 10 per cent above the background brightness, but the natural processes in the atmosphere that are generating light could be 50 per cent or higher. I'm concerned about five or 10 years from now, when there might be a 100,000 satellites in Earth orbit. Our model predicts that the contribution above the background brightness becomes higher. Does that start to impact what stargazers see? It's very likely, and it's going to make it harder to see faint stars.

**Is this a problem for professional observatories?**

Yes, because they can see fainter things than most amateur photographers. If you want to achieve a certain minimum brightness of objects in your image and you have a telescope of a given size, one way to do that is by taking a longer exposure to get more photons from the target object. If you are observing something that's very faint, it may take hours of exposure to get to that amount of signal. However, if the level of background brightness in the sky increases, you will need an even longer exposure and take more time to get the same result. In other words, you may not be able to observe as many objects in a given amount of observing time.

**Will space-based observatories be affected?**

It is a concern for space-based observatories. At least one Hubble Space Telescope image has a Starlink trail through it. Most of the satellites that are intended to be launched will be at higher orbits. Above 600km or so, a satellite will be in sunlight for almost all its orbit in the summer, so it will be illuminated all night long.

**Dr John Barentine** is director of conservation at the International Dark Sky Association

**What is being done to mitigate the issue?**

There is an ongoing dialogue between the space industry and the astronomical community. Operators like SpaceX have been making changes to try and make their objects less reflective, but there's not a lot that can be done to curb the effect that we're talking about in our paper. We are looking at how much the satellites raise the background brightness level of the sky. The reflectivity of the satellites is part of that and reducing that reflectivity will lower the impact of the diffuse sky brightness, but it doesn't eliminate it. The only way to avoid this problem would be to have fewer objects orbiting our planet.

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# THE SOUTHERN HEMISPHERE

**With Glenn Dawes**

Enjoy the Summer Triangle in the northern sky and Jupiter and Saturn at their brightest

## When to use this chart

**1 Aug at 00:00 AEST (14:00 UT)**
**15 Aug at 23:00 AEST (13:00 UT)**
**31 Aug at 22:00 AEST (12:00 UT)**

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

### AUGUST HIGHLIGHTS

Jupiter and Saturn are spectacularly displayed this month with both planets reaching opposition. Crossing the meridian close to midnight, these gas giants dominate the northern sky in a region devoid of bright stars. Both planets are at their brightest with Jupiter only outshone by Venus. Being closest to Earth, the planets present impressively larger images than normal. This is an ideal time to look for features on Jupiter such as the Great Red Spot and Saturn's rings.

### STARS AND CONSTELLATIONS

In the northern evening sky lies the Summer Triangle, composed of three stars. The bottom two are Vega (Alpha (α) Lyrae) in Lyra (left) and Deneb (Alpha (α) Cygni) in Cygnus (right). At the top is Altair (Alpha (α) Aquilae) in Aquila, with the names relating to eagles. However, Altair, along with two flanking naked-eye stars, was also part of the Tarazed asterism, from the Persian 'the beam of the scale'. Tarazed (Gamma (γ) Aquilae) is now the name of the group's (lower) northern member.

### THE PLANETS

The evenings in August display six of the seven planets with the exception being Uranus, which doesn't rise until midnight (mid-month). Mars continues its slow decent in the western twilight glow and Mercury returns to the evening, making a close approach to Mars (0.2° apart) as it passes on the 19th. Mercury is the brighter, but neither can hold a candle to Venus, above. The eastern evening sky belongs to Saturn and Jupiter, with both visible all night, and Neptune arrives early evening.

### DEEP-SKY OBJECTS

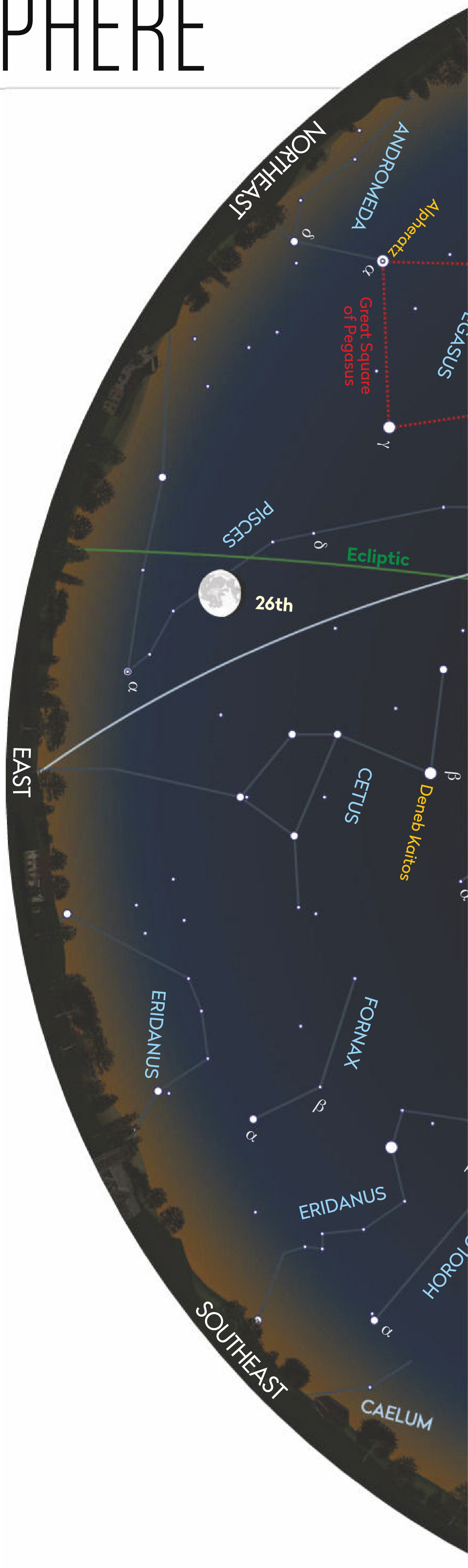
At first glance the multiple star Xi (ξ) Scorpii (RA 16h 04.4m, dec. –11° 22') shows only two stars, mag. +5.0 and +7.3, comfortably separated by 7.9 arcseconds. A closer look shows the brighter component consists of two nearly matched 5th magnitude stars at 1 arcsecond apart. Being binaries (orbital period 46 years), you are fortunate to catch them at their maximum separation. Only 4 arcminutes south of Xi Scorpii is another double of mag. +7.6 and +8.0 stars, 12 arcseconds apart – an attractive eyepiece field!

Move eastward by 7° to cross into Ophiuchus and discover M107 (RA 16h 32.5m, dec. –13° 03'). This 8th magnitude globular cluster has a dense 2-arcminute core with a loosely packed halo of stars reaching to about 6 arcminutes in diameter. A pair of 8th magnitude stars (2 arcminutes apart) are 0.4° to the west.

### Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE




NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
CYGNUS
LYRA
Vega
Deneb
Summer Triangle
Northern Cross
LACERTA
NGC7000
M39
M29
Cygnus Rift
Struve 2470
Struve 2474
M57
M56
Veil Nebula Complex
VULPECULA
SAGITTA
M27
DELPHINUS
Collinder 399
M71
Altair
Tarazed
AQUILA
EQUULEUS
M15
Enif
Keystone
HERCULES
Rasalgethi
Rasalhague
SERPENS CAUDA
OPHIUCHUS
SERPENS CAPUT
Steering Wheel
Circlet
M2
AQUARIUS
NGC 7009
Jupiter
Saturn
Neptune
23rd
Pluto
20th
M11
SCUTUM
M14
M12
M10
M5
Celestial Equator
M25
M17
M75
M9
M107
NGC 7293
PISCIS AUSTRINUS
M30
CAPRICORNUS
M20
M8
17th
Fomalhaut
MICROSCOPIUM
SAGITTARIUS
Teapot
NGC 6522/6528
M80
M7
M6
M62
M4
Antares
SCULPTOR
GRUS
CORONA AUSTRALIS
SCORPIUS
LIBRA
INDUS
PAVO
NORMA
LUPUS
PHOENIX
TUCANA
ARA
HYDRA
47 Tucanae
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CIRCINUS
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APUS
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MUSCA
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Coal Sack
RETICULUM
MENSA
CHAMAELEON
CRUX
NGC 2070
LMC
DORADO
Southern Pleiades
PICTOR
VOLANS
CARINA
Eta Carina Nebula
Canopus
False Cross